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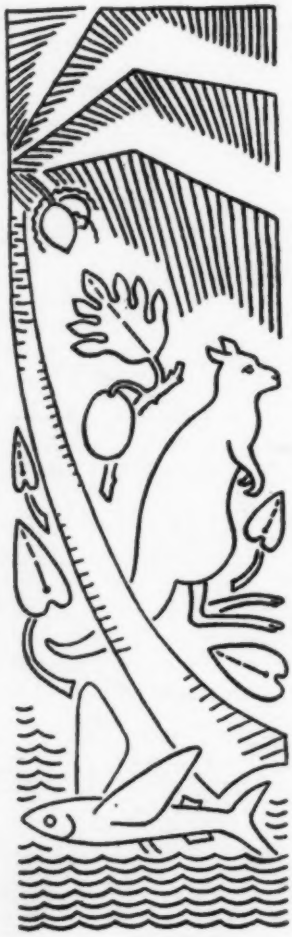

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(Continued on inside back cover)

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The Evolution of Vermetid Gastropods

J. E. MORTON[1]

SEVERAL FAMILIES of prosobranch gastropods are preadapted, by the possession of efficient cleansing mechanisms–the cilia and mucous tracts of the pallial cavity–to adopt a method of ciliary feeding. It is thence a natural development to take on an immobile habit, either buried beneath the surface of soft sand or mud (as in the Turritellidae [Yonge, 1946] or the Struthiolariidae [Morton, 1951*a*]); or attached firmly to a hard substratum (Calyptraeidae, Capulidae, and Vermetidae, [Yonge, 1938]). The gastropods known collectively as the vermetids are one of the most specialised of the latter groups: they have altogether abandoned the regular coiling of the typical gastropod and the shell has become untwisted and vermiform, attached to, or embedded in the substratum. In previous papers (1951*a*, 1951*b*, 1951*c*, 1953) the present writer has dealt in some detail with the structure and systematics of the vermetids, and it has been demonstrated that the classically recognised family Vermetidae must be broken into two very distinct groups–the Vermetidae s. str. and the Siliquariidae. Each of these has been derived, probably separately, from a free-moving regularly-coiled prosobranch stock. It has been thought useful here to sum up in a short space the adaptive features of these two families and to discuss the separate evolutionary trends they have followed.

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THE VERMETIDAE

The first detailed accounts of the feeding habits or adaptive morphology of vermetids were given by Boettger (1930) with a description of *Serpulorbis gigas*, followed by Yonge (1932) with a discussion of *Vermetus novae-hollandiae* of the Great Barrier Reef. Yonge concluded, on the basis of the widely different feeding mechanisms revealed in *Serpulorbis gigas* and *Vermetus novae-hollandiae* (see also Yonge and Iles [1939]) that these two vermetids belonged to widely separate groups, and that "the taxonomy of the Vermetidae clearly requires revision in the light of these results." Yet in this series of genera, the result of further work (Morton, *op. cit.*) on *Serpulorbis* and *Novastoa* and a fuller knowledge of *Aletes* (McGinitie and McGinitie, 1949: 366) was to bring together a large range of forms into a single sequence and to show that the ciliary feeding in *Vermetus novae-hollandiae* and the mucous trap feeding of *Serpulorbis gigas* are the extreme forms in a single evolutionary process.

Of the genera now included within the Vermetidae s. str. seven are dealt with here, namely *Vermetus*, *Petaloconchus*, *Novastoa*, *Spiroglyphus*, *Bivonia*, *Aletes*, and *Serpulorbis*. Of the two examples selected from *Serpulorbis*, *S. gigas*

is a mucous trap feeder, and *S. zelandicus* differs widely from it, still making considerable use of its ciliary feeding mechanism.

We may regard *Vermetus novae-hollandiae* of Yonge's account (1932) as the most primitive known type of the Vermetidae (Fig. 1*a*). It is entirely a ciliary feeder, which must have been the original mode of life of all the Vermetidae after their development of the attached position; it lives cemented to coral or to calcareous algae on the wave-beaten shore line of the Great Barrier Reef and the tropical Pacific. Its shell tube is stout and straight with the sculpture concealed by encrusting growth. The foot is short and plug-shaped and bears a broad, saucer-shaped, chitinous operculum, overlapping a good deal at the sides of the foot. The gill is very large, and the ciliary currents, especially of the lateral and frontal fields, are very powerful. The filaments are, however, primitively triangular in shape, and form the least modified type of gill among the ciliary feeders discussed by Yonge (1938). There is a large pedal gland extending backwards from the haemocoele of the foot into the cavity of the head and trunk, below the buccal mass and alongside the oesophagus. The sole of the foot, which formed the original creeping surface, is now greatly reduced, forming a small triangular area immediately in front of the mouth. Mucus is discharged from the pedal gland upon this area of the foot through a duct opening immediatel iny front of the foot; its aperture is flanked by a pair of short, stout pedal tentacles, unciliated except for a groove along their mesial sides, by which mucous secretion is carried to their tips. So far as can be ascertained the mucus of the pedal gland has little or no connection with feeding in *Vermetus novae-hollandiae*—it appears to perform a role of cleansing the surface of the head and foot adjacent to the mouth and carrying away rejected particles. Within the mantle cavity, extending along the right side of the roof and the right side of the floor respectively, are two further mucous glands forming wide epithelial tracts. The first is the hypobranchial gland forming a normal part of the pallial equipment in all prosobranchs and apparently little concerned with feeding in *Vermetus*. The other forms a food tract by which collected food particles deposited by the gill on the right side of the pallial floor are swept forward by long cilia to the region of the mouth, where they are seized, in small mucous boluses, by the radula.

Though powerfully ciliated, the gill filaments of *Vermetus novae-hollandiae* are otherwise little specialised, and it is probable that the Vermetidae first originated as ciliary feeders of a type like this species. In rough water on a wave-beaten shore ciliary feeding is obviously much more efficient than the use of mucous traps. Calm water and some amount of shelter are required, in order to allow the use of the pedal gland in feeding; which is done to some extent by almost all the remaining members of the family. In retaining the more primitive feeding mechanism of the family, *Vermetus novae-hollandiae* has remained well-adapted to life in rough water.

Two relatively primitive genera of the Vermetidae, which, like *Vermetus novae-hollandiae*, retain a fully developed operculum are the New Zealand *Novastoa* (Fig. 1*b*) and the American *Spiroglyphus*. From the structure of the operculum, the radula, and the embryonic shell, these two genera are evidently very closely related (Morton, (1951*c*)). A similar level of evolution has evidently been reached by the American *Petaloconchus* which the writer has handled only as fixed material, and has not watched feed. In *Novastoa lamellosa*, which we may take as a stage of evolution next advanced upon *Vermetus novae-hollandiae*, the chief means of food collection is still by cilia, and this species frequents disturbed water where mucous traps would be liable to dislodgment (Cranwell and Moore, 1938). The filaments of the gill are triangular and rather unspecialised and the pallial cavity has a ciliated food tract along its right floor. Here, in addition, the pedal gland is a long, well-developed strap passing well backwards into

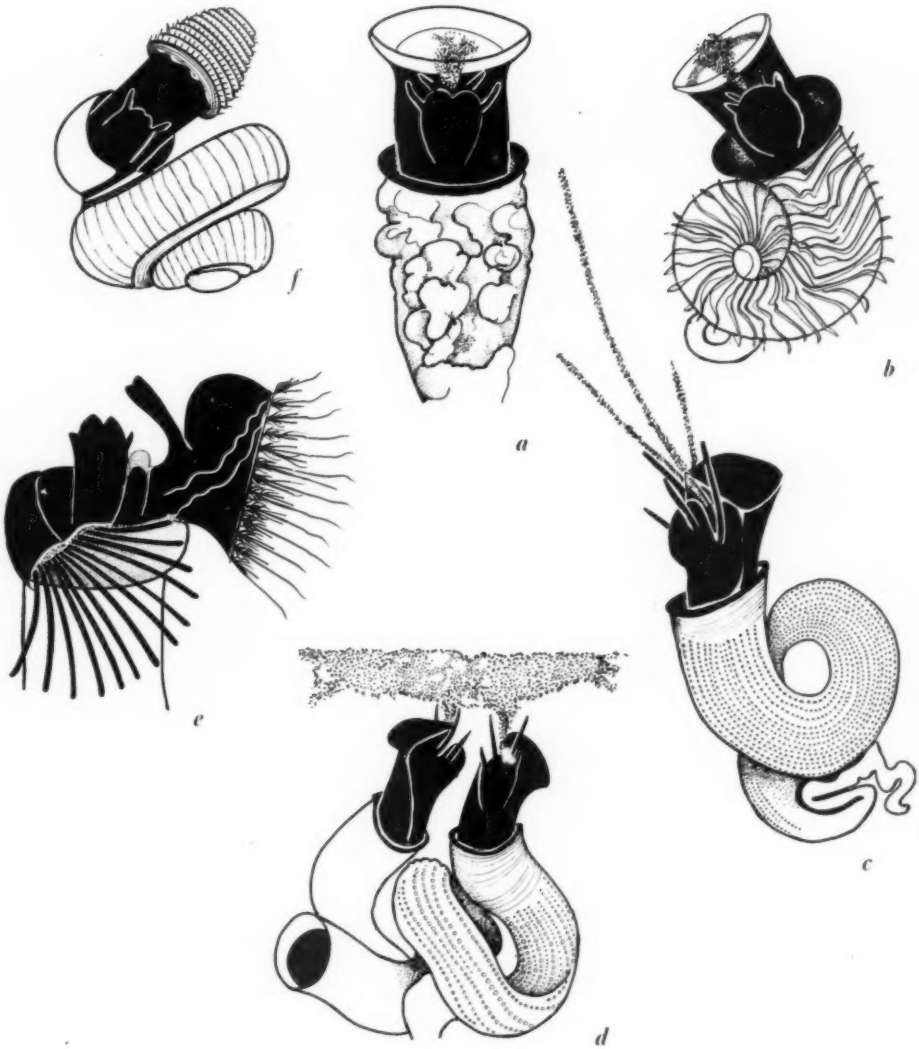

FIG. 1. Semidiagrammatic views of the animal and shell in four genera of Vermetidae and two genera of Siliquariidae. *a*, *Vermetus*, based on *V. novae-hollandiae; b*, *Novastoa*, (*N. lamellosa*); *c*, *Serpulorbis*, (*S. zelandicus*, with mucous trap extended during feeding); *d*, *Aletes*, (a pair of *A. squamigerus* with portion of the communal mucous sheet); *e*, *Stephopoma* (*S. roseum*, with the feeding fringe of gill filaments extended); *f*, *Siliquaria* (based on *S. maoria*).

the haemocoele of the trunk. Fairly constantly, while the animal is feeding, the gland extrudes a small triangular or conical mass of mucus which hangs indecisively over the edge of the foot. The mucous gland of the foot is here evidently beginning to develop a feeding as well as a cleansing function; but although the animals were watched during a long period of feeding by the aid of water goggles, the mucous traps with their collected particles were never seen to be ingested and the disturbance of the water surface by wave action often impeded their proper formation.

The gill in the Vermetidae never becomes more specialised than at the *Vermetus-Novastoa* level; on the contrary two other trends have begun to appear, to a greater or lesser extent, in all the other members of the family: a loss of reliance on the pallial organs in feeding, and the exploiting of the pedal mucous gland, which in every member of the family is already prominently developed.

Serpulorbis zelandicus (Fig. 1*c*) is probably typical of the Vermetidae which are beginning to undertake mucous feeding. This species undoubtedly uses the gill in feeding to a major extent (Morton, 1951*a*) and also puts out long slender mucous strings from the pedal gland, which are evidently drawn in by the pedal tentacles or the radula, and ingested after they have become loaded with microscopic particles. The pedal gland is very stout in *Serpulorbis zelandicus*, much more so than in *Vermetus novae-hollandiae* or *Novastoa lamellosa* (where it is still relatively narrow) and more nearly resembles in extent that of *Serpulorbis gigas*. The ciliary feeding mechanism of the pallial cavity has, however, undergone hardly any reduction as yet; the gill filaments are large and triangular and prominently ciliated, and although, as is always the case in Vermetidae, there is no glandular "endostyle" running along the gill axis the ciliated and mucus-producing food tract is strongly developed. The cross-section (Fig. 3) across the trunk and pallial cavity illustrates the location of the glandular tracts; the hypobranchial gland is well-developed too, although it plays little part in supplying mucus for food collecting.

The serpulorbids have two further modifications which can be regarded as being associated with the feeding adaptations. First, the operculum is entirely lost and the terminal disc of the foot is naked and generally bright coloured. Its edge is very thin and mobile and may easily be indented or retracted at any point so that the formation of mucous strings and their employment is not impeded, as would be the case in the presence of the rigid edge of a projecting operculum. The sole of the foot is also very small in *Serpulorbis*, and relatively much less conspicuous than in *Vermetus novae-hollandiae* or *Novastoa lamellosa*. The loss of the operculum makes necessary the power of quick retreat into the shell; and this is probably correlated in turn with the tendency of the shell in *Serpulorbis*, *Aletes*, and *Bivonia* to become long and vermiform, of far greater length than is normally occupied by the animal. However, other factors no doubt enter into the determining of shell form, or lack of it, in vermetids; thus in genera such as *Novastoa* and *Spiroglyphus* which do not retreat deeply, but rely on large opercula, the shell also tends to become elongated. Moreover, in some of the species of *Serpulorbis* the deeper parts of the shell are cut off by septa. The length of the visceral mass also increases in the species of *Serpulorbis*, whereas in *Vermetus* and in many specimens of *Novastoa lamellosa* the visceral mass, including the posterior lobe of the digestive gland, is rather short and blunt.

A related adaptive trend in the evolution of the Vermetidae is the development of a long median slit in the mantle of the female; this is associated with the protection of the eggs, which in all genera of the family are retained in capsules within the mantle cavity until the emergence of the crawling benthic embryo with its regular spiral shell. In *Novastoa*, *Petaloconchus*, and *Vermetus*, and almost

certainly in *Spiroglyphus*, the egg capsules remain unattached, lying freely within the mantle cavity. But in the nonoperculate forms which retreat quickly into narrower parts of the shell, egg capsules so retained would be liable to damage during the rapid withdrawal of the head and foot into the mantle cavity as the animal darts into the shell. By means of the pallial slit a row of three or four egg capsules can be attached directly to the inner surface of the shell by short stalks. On the retreat of the animal, the capsules remain attached near the mouth of the shell; as the animal again expands the mantle wall extends forward around them.

The genus *Bivonia*, of which the Mediterranean species *triqueter* is the best known example, appears to have reached the *Serpulorbis zelandicus* stage of evolution. The operculum however remains as a small button-like vestige upon the terminal disc of the foot. The shell is long, irregular, and vermiform, and the animal retreats deeply and has a slit mantle in the female. According to Yonge (1932), mucous traps are formed by the pedal gland, but in addition the gill remains well-developed.

The most advanced group of Vermetidae, in feeding habits, is probably that typified by *Serpulorbis gigas*, whose feeding mechanism has been described in great detail by Boettger, and *Aletes squamigerus*, of which the McGinities (1949) have given an account. There is also a brief general description of the feeding habits of the latter and a good figure in Ricketts and Calvin (1948). In both these species mucous traps have entirely replaced the cilia of the pallial cavity in feeding. The gill is very small and insignificant, and the ciliary tracts and glandular region of the pallial floor much reduced in importance. No doubt strong inhalant and exhalant currents, if present at the opening of the mantle cavity, would impede the full employment of mucous traps. In *Serpulorbis gigas*, mucous strings are extruded, which reach 8 or 9 inches in length, i.e. several times the average length of the animal. These are waved about gently with the slight movements of the surrounding water and presently withdrawn and ingested with the food particles that have become attached to them. It is claimed by Boettger that *S. gigas* captures small zooplankton in this way, and in one case, the presence in the stomach of numerous small shells of gastropods (possibly veliger larvae?) was reported. Yonge (1932) maintained that the crystalline style and gastric shield were lost, with the abandonment of ciliary feeding. Later Yonge and Iles (1939) reported the presence of a small gastric shield of greatly reduced extent. A dissection of fixed *Serpulorbis gigas* by the present writer reveals a style sac and gastric shield of similar proportions to that of *Serpulorbis zelandicus;* in *Aletes*, too, the stomach has its normal structure with a prominent style sac and shield. The loss or reduction of the crystalline style is thus evidently not an accompaniment of this type of mucous feeding in vermetids, and the mode of action of the stomach conforms to that of style-bearing prosobranchs in general, as discussed by Morton (1952).

In *Aletes squamigerus*, (Fig. 1*d*) the reduction of the gill has been accompanied by great development of the pedal gland as in *Serpulorbis gigas*, but here, instead of the formation of long separate strings, the extruded mucus takes on the form of a continuous sheet and feeding becomes the combined activity of a large cluster of gregarious individuals. As described by the McGinities (1949), "When the animals occur in clusters, the fan-shaped sheets of mucus they put out become entangled, and the table with its bill of fare becomes a community affair. When one member in such a group begins to eat the mucus sheet, all the others start swallowing. The sheets of mucus may extend upward into the water for five or six inches."

The demarcation of genera in the *Aletes-Serpulorbis* series is at present a very uncertain proceeding. There would appear to be no well-marked conchological characters to discriminate between forms such as *Serpulorbis*

zelandicus, which have continued to make good use of the gill in feeding, mucous trap feeders like *S. gigas*, and mess-table feeders like *Aletes squamigerus*. The adult shells are markedly similar and devoid of diagnostic features. Evolution in sculptural detail has tended to become retrograde and is moreover often obscured by encrusting organisms or becomes obsolete on the older parts of the shell. The radulae in the above three species are extremely similar and thus unhelpful. The most natural means of separation would at present appear to be by reference to the condition of the gill and the ciliary tracts of the mantle cavity, which is of small help to the conchologist faced with a range of cabinet material. Perhaps the most valuable character will be found in the sculpture of the embryonic shell; and here the careful work of Dr. Myra Keen on the American vermetids will be eagerly awaited. It is possible that the *Aletes-Serpulorbis* group should have the status of a single worldwide genus, when judged on shell characters; if this is so, it will be a genus in which evolution of the animal and its mode of life has greatly outrun the changes in conchological features.

THE SILIQUARIIDAE

In the second family now recognised, the Siliquariidae, the shell never loses its roughly spiral general form; though as a general rule the spire loosens up to become open and corkscrew-shaped. The tube is never cemented to the substratum along the whole of one side, as in the most advanced and least regularly coiled members of the Vermetidae; it is usually, as in *Stephopoma*, loosely immersed in the encrusting growth on rocks, or, as often in *Siliquaria*, embedded in sponges. Mucous traps are not used in feeding and the pedal gland does not become greatly enlarged as it is in all the Vermetidae. In all cases the ctenidial filaments are employed in food collecting and they have become much more modified than the primitively triangular filaments of the vermetid type. The pedal tentacles are never present, and the sole of the foot, while reduced in extent, is usually clearly recognisable in the adult and considerably more conspicuous than in the Vermetidae.

The account by Morton, (1951*b*) describes in detail the mode of feeding of a member of the Siliquariidae, *Stephopoma roseum*. The more normal method of food collecting, with the gill retained in the pallial cavity, is clearly not very different from that of *Turritella* (Graham, 1938). The gill is also however employed in a "sweeping fringe" type of feeding activity, which has not been observed and recorded in any other gastropods. The gill filaments have become narrow and cirriform, and lie across the pallial cavity to form an oblique lamina extending from its insertion on the left across to the food groove on the right. A continuous water current is drawn into the pallial cavity by the action of the lateral cilia of the ctenidium, and is passed between the filaments from the ventral (frontal) to the dorsal (abfrontal) side. Food particles themselves, entangled in mucus secreted by the endostyle, are carried along the filaments to the right side of the pallial cavity, chiefly by the frontal cilia, to a lesser extent by the abfrontals. The "food groove" does not form a wide glandular sheet as in the Vermetidae, and correspondingly less mucus is derived from it. The greater part of the binding substance of the food string comes from the endostyle and, as in the Vermetidae also, the hypobranchial gland appears to contribute little if any mucus to the food string. The tips of the ctenidial filaments are rounded, somewhat expanded, and bulbous, and anterior filaments crowd like a cluster of fingers into the wider portion of the food groove.

During normal feeding, a number of ctenidial filaments protrude across the free edge of the mantle, and when the animal is fully extended from its tube a fringe of radiating filaments forming about one-fourth to one-third of the total length of the gill projects from the mantle. Frequent sweeping move-

ments are performed with this fringe which, because of the flexibility of the filaments, is curved downwards below the margin of the shell, and then, more rapidly, the fringe is suddenly flexed. Particles engaged by the separate filaments travel towards the apices by the action of the frontal cilia, embedded in a copious secretion of mucus from the axial endostyle, which secretion appears to be immediately induced by the contact stimulus of the particles upon the surface of the filament. At the same time the lateral cilia, normally in rapid motion, become motionless; this is of obvious advantage during the "sweeping fringe" type of feeding, in preventing the loss of the endostylar mucous secretion by passage between the filaments during the beat of the lateral cilia. At the tips of the filaments another set of cilia, arranged in long apical tufts and generally kept inert, now comes vigorously into play. The cord of particles collected in mucus, which now extends from tip to tip around the fringe of filaments, is carried by the apical cilia towards the mouth where it may either be accepted for ingestion or, as is usually the case with experimental carmine particles, cast off the filaments and rejected.

The modifications undergone by the foot in *Stephopoma* can be best appreciated by reference to Figure 2*b* which represents an embryo recently liberated from the maternal pallial cavity and just beginning its brief period of free crawling. In the adult *Stephopoma*, the foot is prolonged in front of the mouth into a long, flattened or spatuliform lobe, the pre-pedal process. This displays a rather complicated set of ciliary currents which evidently assist in the ingestion of the mucous cord from the food groove, or in the rejection of loose particles alighting near the mouth, probably both. It is formed by the large anterior margin of the foot which is squarish, strongly ciliated, and very labile in the embryo. In the adult, it becomes narrowly constricted from the rest of the sole of the foot which remains in the form of a broad cushion of whitish, ciliated and glandular epithelium, lying, in

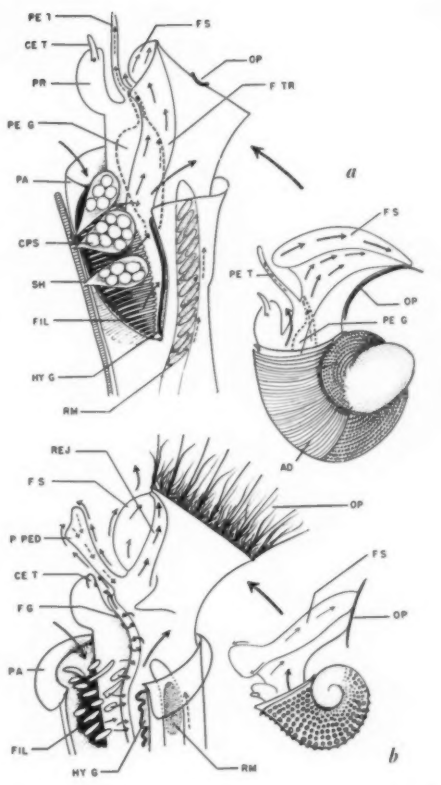

FIG. 2. Diagrams illustrating the structural differences between the families Vermetidae and Siliquariidae. *a*, *Serpulorbis*. Section of the head and foot and the free crawling embryo; *b*, *Stephopoma*. Section of the head and foot and the free crawling embryo. In the figure of *Serpulorbis*, the contents of the pallial cavity are displayed through the natural cleft in the female, through which the egg capsules are attached to the shell. In *Stephopoma*, the pallial cavity has been opened by the removal of a portion of its right wall, to display the tips of some of the ctenidial filaments in end view. The arrows indicate the directions of the principal ciliary currents. In the embryos note the spirally coiled embryonic shell, and compare with the figures of the adults, to see the modifications involved in the development of the head and foot.

AD, Adult portion of the shell added to the nuclear shell in *Serpulorbis;* CE T, cephalic tentacle; CPS, egg capsules; F G, food groove in *Stephopoma;* FIL, gill filaments; F S, sole of the foot; F TR, food tract in *Serpulorbis;* HY G, hypobranchial gland; OP, operculum; PA, mantle; PE G, pedal gland; PE T, pedal tentacle; P PED, pre-pedal process in *Stephopoma;* PR, proboscis; REJ, rejectory tract of foot; RM, rectum with faecal pellets; SH, shell.

the normal position of the parts, in front of the proboscis. At the sides of this cushion, excurrent grooves carry particles of detritus and rejected debris off the surface of the sole. The anterior lobe of the foot contains a nest of mucous glands in the embryo, which—far from becoming enlarged in the adult—appears to be lost almost entirely. The epithelial covering is, however, well-supplied with mucous glands which serve for the cleansing of the foot. The whole of the mucous supply for food collecting is produced in the pallial cavity, chiefly from the endostyle.

In the embryo of *Stephopoma* the operculum is a simple chitinous disc, slightly concave, carried on the back of the still functional foot. In the adult it becomes very large, overlapping the border of the foot, and densely setose. It consists of a spirally coiled chitinous band, each whorl fringed with long, branched setae, those on the final whorl the longest and extending far beyond the edge of the disc. The present writer has fully described elsewhere this operculum and the structure of its bristles (1951*b*) and has discussed a possible adaptive explanation of its structure. When the bristles are in contact with the edge of the shell aperture they have a screening and filtering action which prevents larger particles entering the pallial cavity. The animal may apparently feed for considerable periods of time in this position with the disc of the operculum close against the aperture and the sweeping fringe of gill filaments not extended. Deep withdrawal into the tube is a feature of some of the siliquariids as well as of the true vermetids. In *Stephopoma* it is made possible by the flexibility of the opercular bristles, which may be recurved upwards against the inner wall of the shell when the animal is fully retracted although their full spread is considerably wider than the aperture. Whether the adaptive explanation of opercular specialisation is the full one is rather doubtful. Quite possibly the elaborate form of the bristle crown, and especially the interspecific differences in the bristles in *Stephopoma* (see the old paper of Mörch, 1861), is, as must be the structure of the operculum in *Siliquaria*, a non-adaptive specialisation—one of those extravagances of evolution which seem so often to recur among gastropods at the level of family and generic systematic characters.

The second section of the Siliquariidae contains those wormlike gastropods truly assigned to the genus *Siliquaria* (s. lat.). Here the shell may be long, slender, and corkscrew-shaped, delicate and translucent as in the subgenus *Pyxipoma*, or squat and much heavier as in the *Agathirses* series. In all cases, however, its spiral shape is retained, and along the right side runs a long spiral slit (reduced in some cases to a row of holes) corresponding with an internal fissure along the exhalant side of the pallial cavity. *Pyxipoma weldii*, from New Zealand and Australian waters, was the only siliquariid studied alive. It corresponds very closely in organisation with *Stephopoma*, and the latter genus was placed alongside the fissured "vermetids" in the Siliquariidae by Morton (1951*b*). Characters in common are the structure of the foot, its absence of pedal gland and tentacles, and the nature of the ctenidial filaments which are narrow and linear, quite distinct in form from those of the Vermetidae. In *Pyxipoma* the supplementary mode of feeding by means of the "sweeping fringe" has not been observed, though the general arrangement of the pallial organs makes such a mechanism quite to be expected. The food groove, as in *Stephopoma*, forms a deep ciliated gutter, with no great development of mucous glands. The "endostyle" along the gill axis is large and highly glandular.

The fissured shell is of much less taxonomic importance in marking the limits of the siliquariid group than has been hitherto supposed. The present writer proposed (1951*b*) to take as the chief diagnostic feature of the family the embryo shell, which is one and one-half whorled, coiled in an almost plane spiral, with a wide, slightly effused trumpet mouth, marking it off clearly from the adult shell,

with which it is set in the same axis, in strong contrast to the condition in the Vermetidae. The general mode of coiling of the shell, which is never internally septate, as well as the form of the dentition, are also good distinguishing characters of the Siliquariidae. The structure of the operculum, which is always prominently retained, is equally typical; it consists always of a spirally coiled band, bearing a fringe of setae, elaborate in *Stephopoma*, much more simple in *Pyxipoma*. In the latter genus, the operculum is raised to form a tall dome, built up of a spirally rolled band, enclosing a core of triangular cells arranged about a central axis. The setae here are never elaborate, and the operculum fits tightly over the aperture so that the animal is unable to retreat deeply into its tube.

The significance of the spiral shell fissure in the siliquariids is perhaps not yet fully understood; but it is undoubtedly in part an adaptation of the same type as the primitive shell fissure in many Archaeogastropoda, by which the exhalant water current is released. Such a feature is not of course a primitive one in the Siliquariidae, but rather a reacquired character in members of a highly specialised group. Extra efficiency of the exhalant water current is an obvious advantage in a siliquariid living, as is common, in turbid waters on a highly sedimented substratum; moreover, the siliquariids lack the protective straining mechanism which may be provided by the long opercular bristles in *Stephopoma*. The presence of an exhalant slit is perhaps also of adaptive value in the sudden and rapid withdrawal of the animal, which frequently darts back into the tube and closes the operculum tightly over the aperture. No expulsion of water is possible between the bristles of an opercular fringe as in the case in *Stephopoma*. Such an explanation of the shell fissure appears the most probable one in *Agathirses* and those siliquariids which do not deeply embed themselves in the substratum. Its presence makes much less sense in *Pyxipoma* which is in its habit more specialised, spending its whole life embedded in a

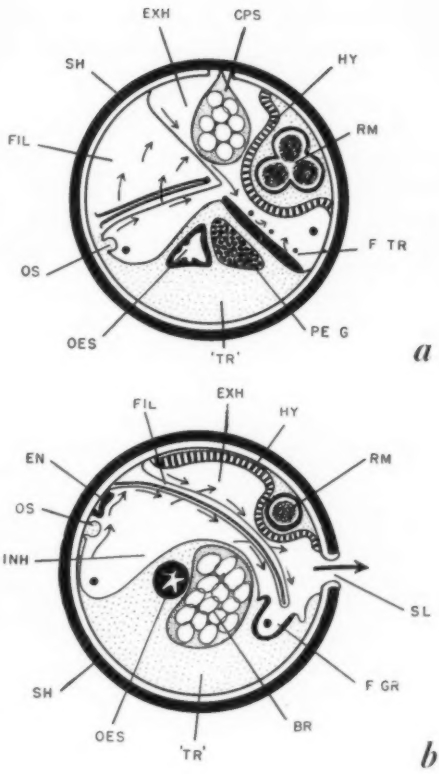

FIG. 3. Diagrammatic transverse sections to illustrate differences between the vermetid and siliquariid organisation of the pallial cavity. *a*, *Serpulorbis* (Vermetidae); *b*, *Pyxipoma* (Siliquariidae). The arrows show the direction of the principal ciliary currents. These figures should be examined together with the diagrams of Figure 2.

BR, Brood pouch in *Pyxipoma;* CPS, egg capsule in *Serpulorbis;* EN, endostyle; EXH, exhalant chamber of pallial cavity; FIL, gill filament with tract of lateral cilia indicated; F GR, food groove in *Pyxipoma;* F TR, food tract in *Serpulorbis;* HY, hypobranchial gland; INH, inhalant chamber of pallial cavity; OES, oesophagus; OS, osphradium; PE G, pedal gland; RM, rectum with faecal pellets; SH, shell; SL, exhalant slit in *Pyxipoma;* 'TR,' muscular region of "trunk" formed by columellar muscle flooring haemocoele.

mass of sponge, as far as the extreme edge of the aperture. Any advantage once derived from an accessory exit from the pallial cavity would seem here to have been entirely sacri-

ficed, especially as the slit in the shell becomes very narrow, at times almost obsolete, and is always occluded by the overgrowth of sponge tissue and spicules across it.

Adaptations for the protection of the embryos must be briefly mentioned for the Siliquariidae. In *Stephopoma*, the embryos with their trumpet-mouthed shells, enclosed in a thin egg capsule, are simply held freely in the mantle cavity of the parent, as is the case in the more primitive members of the Vermetidae. In *Pyxipoma* there is a spacious brood pouch excavated in the cavity of the head, immediately below the buccal mass and the oesophagus. It opens to the exterior by a small circular aperture on the right side at the termination of the ciliated oviducal groove running forwards from the female aperture, and close to the termination of the food groove below the right tentacle.

No species of the genus *Vermicularia* appears to have been examined from living material. The present writer (1951*b*) suggested reasons for its transfer to a position alongside the siliquariids, pointing out that in its structure it was certainly unlike any of the gastropods properly belonging to the Vermetidae. Following access to a better supply of preserved material of *Vermicularia spirata*, the close relationship of this genus with both the Siliquariidae and the Turritellidae is fully confirmed. It forms an interesting example of a form intermediate in structure, and presumably in habits, between the freely moving, ciliary feeding turritellids and the fixed or embedded siliquariids as has been indicated in a more recent discussion (Morton, 1953):

> *Vermicularia* then has close relationships with *Turritella* in the pallial tentacles, and the structure of the gill, the food groove and the foot; as well as in the radula, the embryo shell, the operculum and the ontogeny and sculpture of the adult shell. On the other hand, it is close to *Stephopoma* in many features, such as the uncoiled shell, the sessile "vermetid" habit, and the greater elongation of the gill filaments . . . . In choosing with which family the genus Vermicularia should most properly be placed, we should probably select the Turritellidae, which would enable the Siliquariidae to be reserved for those sessile forms with reduced, trumpet-mouthed apices. But the relationship of *Vermicularia* to both is very close and there can be little reason to doubt that the genus is near the point at which a deposit feeding prosobranch with a turritellid organisation gave rise to one or more lines of sessile, uncoiled derivatives.

DISCUSSION

To "define" a group of organisms at the family level in terms useful to the systematist is a problem rather different from "characterising" it in such a way as to bring out its interest to the evolutionist. In this case we are concerned less with extreme cases or with anomalies in marginal form, and more with the central pattern of organisation that unifies the family, and with the evolutionary trends being followed within it. These trends would appear in many cases to be of two rather different kinds: there is first the phenomenon of "adaptive radiation" between different genera, and this must account for many of the characteristics of the Vermetidae and Siliquariidae, especially the modifications of the foot and pallial cavity; but there are, further, a number of trends running through each family, often apparently developed convergently in different genera, which seem to be much less closely, if at all, related to adaptation.

It must be obvious that in the vermetid and siliquariid stocks we are dealing with two fundamentally different groups of Mesogastropoda. The writer has already (1951*b*) outlined at length the differences between the two families, and has suggested that the Siliquariidae approach rather closely to the Turritellidae in their affinities. It is much less clear from which group the Vermetidae may have originated, and there seem to be no living mesogastropods which at all clearly suggest an ancestral form. In the development of ciliary feeding within the Siliquariidae and the more primitive section of the Vermetidae, we would seem to have no more than an instance of parallel adaptation. There are moreover several other apparently unrelated groups of prosobranch gastropods which have devel-

oped the ciliary feeding habit as an evolutionary climax feature as mentioned earlier in this paper. They all fall within the wide series of Mesogastropoda bearing crystalline styles or protostyles, and relying strongly upon the action of cilia and mucus in the functioning of both the pallial cavity and of the digestive tract; they are preadapted to give rise to ciliary feeders. A similar potentiality separately realised in different groups is the development of an enzyme-carrying crystalline style (Graham, 1938; Morton, 1952). A common structural pattern and mode of functioning of the stomach is inherited by all of those molluscs, both gastropod and lamellibranch, derived from possessors of a protostyle. The enzymic action of the crystalline style was doubtless acquired separately within these groups in a number of parallel cases.

The diagrams (Fig. 2*a*, *b*) make sufficiently clear the differences in adaptations of the Vermetidae and Siliquariidae, both in the modifications developed in the foot of the adult and the pallial structures present in the embyro. A common ancestor among the microphagous mesogastropods must have had the following structures, or the potentiality to develop them: (1) a crystalline style sac in the stomach, and the mucous string mode of food transport; (2) a pallial cavity with a well-developed gill equipped with strong ciliated tracts for current-producing, cleansing and rejection, and (potentially) three longitudinal glandular tracts within the pallial cavity, a hypobranchial, basibranchial ("endostylar") and infrabranchial (nuchal tract or food groove); (3) a mucous gland of the foot opening anteriorly to the sole, and potentially able to become very large; (4) a small, strong radula of the grasping type, with sharply pointed teeth; and (5) a foot bearing a simple, circular, saucer-shaped operculum. Obviously almost any family of microphagous mesogastropods would satisfy these requirements, and there is very little to indicate that the Vermetidae and the Siliquariidae arose close together.

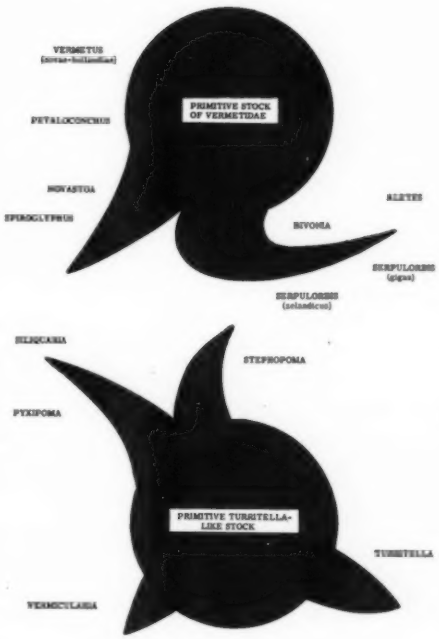

FIG. 4. Scheme to express the relationships and course of evolution of the vermiform gastropods included in the Vermetidae and the Siliquariidae.

The evolution of the two series (Fig. 4) shows first a convergence in the parallel development of ciliary feeding, and then a swinging away of the vermetid line towards more highly specialised mucous feeding. On the one hand, ciliary feeding is continued, with increasing specialisation of the pallial organs (Siliquariidae), on the other, the pedal gland at an early stage assumes a share in the provision of mucus for food collecting. The gill filaments in this series never lose their original triangular form, and in the furthest evolved members of the Vermetidae, the pedal gland is enormously enlarged and the gill tiny and vestigial. In the siliquariids the operculum becomes large and very elaborate; in the vermetids it is finally lost altogether. Parallel with the enlargment of the pedal gland and

the reduction of the gill, the shell in Vermetidae becomes elongated and very irregularly coiled: with the loss of the operculum the animal becomes able to retreat deeply into the shell, and the mantle in the female becomes medianly slit as described above, as an adaptation for fixing the egg capsules directly to the shell. This modification seems always to be associated with the loss of the operculum and the consequent need for deep protective retreats into the shell. The reduction or loss of the operculum may itself be primarily a consequence of the mucous feeding habit, enabling the animal to put out its mucous traps unimpeded by the edge of the operculum, as suggested by Yonge and Iles (1938).

In the group including the Siliquariidae, the Vermiculariidae, and the Turritellidae, we may imagine an ancestral form with a potentiality to develop both elaborate opercular setae and also pallial tentacles—these are the chief diagnostic features of this assemblage, which has been shown to share a large number of structural characters in common. In the genera so far investigated, *Turritella* retains both the opercular setae and the pallial tentacles, *Vermicularia* loses the setae, and in the Siliquariidae the pallial tentacles are not represented. We should not perhaps regard the loss of tentacles or setae in one or other of these groups as being too literally a phylogenetic event; or suppose that an ideal common ancestor possessing each of them ever existed. All that the facts entitle us to suggest is the existence of a common stock which had a tendency to produce evolutionary forms, either of the siliquariid or the vermiculariid type. The Turritellidae perhaps comes closest, among surviving families, to such an ancestral stock but this family is in itself undoubtedly specialised upon a distinct line, and almost certainly gave rise directly to neither.

In the evolution of a radiating group such as the prosobranch gastropods, we are likely to find different adaptive patterns almost from family to family; and the two groups of vermiform mesogastropods illustrate this principle very well. At the level, however, at which families are diversified into genera, it would appear that evolution due obviously to adaptive changes has relatively much less effect. Such a conclusion is best illustrated by the details of shell sculpture and dentition, and, in the present case, by the characters of the nuclear shell and the operculum; and it is in part because of their nonadaptive character that these structures have come to be the most useful ones in a reliable classification. The evolution of other molluscan groups seems often to tell a similar story. We find first a series of adaptive characters setting off a family or a group of families from neighbouring ones, such as, in the vermetids, adaptations to ciliary or mucous feeding. Then, most often at the generic or interspecific level, evolutionary diversity of a different kind seems to enter the picture. In two others groups of gastropods examined by the writer in some detail, the Strombacea (1951*d*) and the Ellobiidae (in press), a similar situation has appeared, and further examples might easily be cited from other groups.

Mollusca evolving at the generic level are uneasy ground for the dogmatic selectionist. In some cases there appear to be features of an "orthogenetic" kind (though this is a word that has acquired some objectionable shades of meaning) running in a parallel way through different, but related series of genera. Many of these trends may force themselves into expression in the history of a group so as to dominate much of its evolution. Thus it happens that many molluscan groups present beautiful examples of adaptive evolution at the family level, and may then become permeated with what appears to be functionally meaningless minor trends, often, as in the case of shell structure, aesthetically pleasing and always interesting to the taxonomist. The selectionist's plea will be that most of these characters, at present inexplicable on adaptive

lines, may on fuller investigation be found to be genetically linked with advantageous features or developmental patterns. Such a stand is less likely to appeal to one looking at, for example, the variety of sculpture found in the nuclear whorls of vermetids or siliquariids, the sculpture pattern of the adult shells, the structure of the operculum in *Siliquaria*, or of its bristles in *Stephopoma*. The selectionist's view has the merit of removing a problem one stage further away; but to try to argue with our present knowledge, any general relation between adaptive influences and the evolution of molluscs at the generic or specific level, is probably to go further than reliable evidence will allow.

In this paper I have given no critical attention to generic nomenclature, but have employed as genera, according to prevailing practice, each of the subgeneric groups recognized by Thiele (1931), in his rather conservative arrangement of the Vermetidae (s.l.). Dr. Myra Keen, of the Department of Geology, Stanford University, California, has recently (August, 1954) outlined to me in correspondence a revision of the genera of Vermetidae (properly so-called) which she will shortly make. From my own study of the soft parts and biology of the family I am in agreement with Dr. Keen's proposals.

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New Zealand Cyrtidae (Diptera) and the Problem of the Pacific Island Fauna.

S. J. PARAMONOV[1]

DURING THE PREPARATION of a review of the Australian Cyrtidae some New Zealand material was used for comparison. The study of this material has shown that a review of New Zealand cyrtids is also required. For the clarification of some systematic problems the author was forced to collect all available information about New Zealand cyrtids, and to write a short, preliminary review of them. The publication of this review, the author thinks, will be useful for New Zealand dipterists. The author quotes the descriptions *in extenso*, because they are dispersed mostly in old, not very easily accessible publications and it will facilitate the undertaking of a more extensive study of New Zealand members of the family.

Comparison of the fauna of cyrtids of New Zealand and Australia has given material for some general conclusions, which can be used in solving the problem of the Pacific fauna.

The representation of Cyrtidae in New Zealand is very poor: 1 species of *Apsona*, 3 species of *Helle*, and 3 species of *Oncodes*, representing three different subfamilies, but it has some significance in the problem of the origin of the Pacific fauna.

To the present time representatives of the genera *Apsona* (Panopinae) and *Helle* (Philopotinae) are not known in Australia and there is no reason to believe that they will be found here in the future.

The author has had an opportunity to study some specimens of *Apsona muscaria* Westwood, the only species of the genus if we do not include *Apsona caerulea* Brunetti from Brazil. (Brunetti has not compared his species with *Eulonchus* and it is difficult to tell to which genus the Brazilian species belongs.) He has found an astonishing similarity between *muscaria* and *Eulonchus smaragdinus* Gerst. from California. The size, shape, colour, structure of integument, venation, hairs, and many other characters are so similar that they can almost be regarded as belonging to the same species. Only detailed study under a lens (see below) shows that they are different, but the generic difference between them is in doubt.

A comparison of all *Apsona* and *Eulonchus* species will doubtlessly show that *Apsona muscaria* Westw. and *Eulonchus smaragdinus* Gerst. are remarkably close or possibly congeneric. Lack of material does not permit the author to state that the two genera are synonymous, but there is no doubt about their very close relationship. The species of the complex *Eulonchus-Apsona* are distributed in New Zealand, North America and South America, but are quite absent from Australia.

The genus *Helle* is comparatively very well represented in New Zealand (three species), whereas no representatives of the whole subfamily Philopotinae are recorded for Australia. Elsewhere the distribution of the subfamily is confined to widely separated areas. In America the genus *Helle* is absent, but *Philopota*, a

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closely related genus, is present.

The genus *Oncodes* is cosmopolitan, but none of the species has been found to occur both in Australia and New Zealand.

Thus the information we have on the New Zealand Cyrtidae would indicate a closer relationship, with respect to their origins, between the New Zealand and American fauna than between the New Zealand and Australian.

Let us now examine the general features of the dipterous fauna of New Zealand. First the absence, or extremely poor representation, of some families must be recorded: *Nemestrinidae*, *Apioceridae*, *Scenopinidae*, *Mydaidae*, *Conopidae* are quite absent; some large families, such as *Bombyliidae*, *Leptidae*, are represented by one species each. What is the cause of this absence? It is quite evident that all these and similar elements of the fauna were present in New Zealand in different geological periods.

During its geological history New Zealand has been repeatedly covered by the sea, but since mesosoic time it has been definitely above the sea and part of a large continent, which was situated mainly westwards of the present position of New Zealand. Australia is also a part of this earlier continent.

In Trias-Jura time New Zealand was more extensive, reaching to New Caledonia or even farther northwards, eastwards reaching the Chatham Islands and southwards to the Campbell Islands.

The main ranges of mountains were created during the Pliocene. The uplift was continued in the Pleistocene. This was the time of the greatest glaciation. The end of the Pleistocene was a time of subsidence when the sea covered the sea-shore zone to a height of 40–150 meters above present sea level. This subsidence changed to slow uprising which has continued.

Thus New Zealand has been connected with land-masses which have representatives of the above mentioned families in great number, and such families were destroyed during the process of New Zealand's isolation.

The causes of this destruction were various: 1) some elements adapted to the arid area conditions were eliminated by the absence in New Zealand of deserts and by very high humidity, 2) some elements were destroyed by the glaciation, which was not very intense, but which changed fundamentally the ecological conditions.

When the author was writing his *Review of Australian Apioceridae* (Paramonov, 1953), he was restricted by the scope of the theme and could not discuss the problem of the absence of the family in New Zealand; now it will be useful to express his ideas in a more extensive form.

If we accept the destruction of apocerids by glaciation, we must examine theoretically the three following alternatives.

1. A large continent (for example, Australia or South America) is undergoing glaciation. Will the result of glaciation be the destruction of the fauna of the continent? Most probably not, because the continent extends from north to south for a very great distance. We cannot suppose glaciation to cover the whole continent. On one or the other end of it there will exist much more mild climatic conditions, which will permit the existence of the different elements of the fauna. Such glaciation cannot wipe out the fauna—the animals will only migrate to the warmer areas or strips of land or "pockets."

If we suppose the whole of the state of Victoria, from the Kosciusco summit to sea level to be covered with snow and ice, we can be sure that in the area of Cape York there will be areas serving as "refugiums" for the different elements of the fauna. Never will the fauna be completely extinct. After the end of glaciation the animals will migrate back into Victoria. The glaciation can cause maximally only the impoverishment of the fauna and temporarily the change of its spatial distribution.

2. We will have a quite different picture if the glaciation covers a not very large island

(for example Tasmania) and is strong and prolonged—the extinction of the fauna will very probably occur. However, if the island is part of a long chain of islands, there is a good chance of reimmigration after the end of glaciation.

3. If we have some large islands with their axis in a north–south direction, and these islands are isolated by very broad ocean areas from all continents and islands (e.g., New Zealand), the extinction or impoverishment of the fauna during strong glaciation is very probable.

From these explanations, I think, it is evident that the comparison of New Zealand with Australia or South America is not well grounded. The general conditions are very different. In New Zealand there is not the possibility of reimmigration of the fauna.

Let us now consider the glaciation. In Australia there never was a glaciation which covered extensive landmasses as by a shield. The glaciation touched only the mountain area and as a result no complete fauna or even the outstanding elements of parts of that fauna were destroyed. There was only temporary redistribution of the elements of the fauna in space.

I think we have a similar condition also in New Zealand, where the glaciation was never so strong as to be able to destroy the whole fauna. Very possibly glaciation was the real cause of the extinction of the apiocerids, because heavy snowfall usually is connected with diminishing temperature, and masses of snow and ice with low temperatures can cause the death of the apiocerids.

But (and this is my main idea) it is not just the glaciation which destroys the whole fauna or large parts of it. Glaciation is the result of a specific combination of meteorological conditions when the snow accumulates more and more, beginning to form ice-shields and penetrating little by little into the valleys, but it does not mean the destruction of the fauna or the depression of its elements.

In Patagonia and Chile we have at present the coexistence of a huge mass of ice and, at a distance of 2–3 hundred metres, a huge, very tall forest. Here we have equilibrium between the elements causing the glaciation and deglaciation, and this equilibrium has existed for at least 100–200 years because the forest near the masses of ice has required such time for growth.

However, there is another type of meteorological combination which can destroy the essential parts of the fauna without glaciation —the periodical or permanent lowering of the temperature in the winter. It is enough to have 5–10–25 years of winters with the temperatures under 0° C., and all the insect pupae in the superficial layer of the soil will be frozen. The apiocerids are a very old group from very warm countries. They have not developed adaptations to cold winters, their pupae always lie shallowly in the soil. A number of winters with temperatures under 0° C. can cause the complete extinction of the apiocerids. It will be useful to remember that in Siberia (Yakutsk area) in the coldest point of the whole world (the temperature in the winter drops to −70° C.) the snowfall is very small, usually so small that horses can find food under the snow during the whole winter.

In such a way we can explain the extinction of apiocerids in New Zealand, not only directly by strong glaciation but also by a series of very cold winters which can destroy those elements of the fauna without adaptation to low temperatures. In my review of Australian Apioceridae I mentioned only glaciation as the cause of impoverishment of the New Zealand fauna, but the above explanation should be taken into consideration, also.

The presence of a very small number of species representing the three subfamilies of cyrtids in the New Zealand fauna shows us that the fauna is very impoverished. The main cause is probably the same as for the other families: glaciation, low temperatures in the winter, and high humidity.

The remnants of the fauna show, however, rather high specialization. It is quite evident

that before the glaciation, etc., New Zealand had many rather peculiar elements. These elements do not show a very close relationship with the Australian fauna, but reflect more an affinity to the American fauna and possibly to the fauna of the Antarctic continent.

At the present state of our knowledge it is difficult to state the cause of the glaciation in New Zealand. If we accept Wegener's theory of the drifting continents, we can accept the drift of New Zealand to the polar area, which destroyed the more warmth-liking elements, and then back-drift to the warmer areas. As a result of the very marked isolation by the vast surface of ocean there was no possibility of receiving again the warmth-liking elements.

If we examine the families of Nematocera and compare them with those of Australia, we will see that no families of Nematocera are absent from the New Zealand fauna, some of them even (for example *Tipulidae*) are represented much better than they are in Australia. In general the nematocerous families are more typical of cold areas throughout the world. This comparative richness of the New Zealand fauna in Nematocera is in close harmony with the drifting theory: New Zealand has received its cold-liking elements from the Antarctic area.

However, there are facts in contradiction to this idea. The family Cordyluridae, which is typical of the cold areas of the Northern Hemisphere, is absent in New Zealand; also the genus *Tapeigaster* (Neottiophilidae) is absent though nine species of the genus are very common in Australia, living on mushrooms. Also, not without significance is the absence of the families Heteroneuridae, Sepsidae, Tanypezidae, and Thyreophoridae (the last family has some representatives in Australia, which live mostly, in the winter, on carrion). The absence of these flies possibly can be explained without difficulty, but, at the present, we do not have enough data about their distribution and life histories to explain it.

In order to attack the problem as a whole we must also consider the presence of some other elements, because the presence of these elements is also important to an understanding of the problem. Whence came the remnants of the warmth-liking elements? Only very few of them are true endemic species of New Zealand, the greater part of the species no doubt did not originate in New Zealand, but only persist there (for example the genus *Helle*). Probably the origin of similar forms was connected with the Antarctic land masses. If we reject the idea of the drift of continents it will be very difficult to explain the origin of forms such as the genus *Helle*. The distance between the Antarctic land masses and New Zealand is so great that if we suppose that the position of the south pole changed so that the whole Antarctic continent was situated in latitudes which would permit the existence of animals adapted to a warm climate, New Zealand would be situated in the tropical or equatorial area. However, there are no equatorial or tropical elements in its fauna (and flora).

We can imagine the complicated relations between faunas if they changed their geographical positions, but if we accept immovability of the continents, an explanation cannot be found. The theory of land-bridges of the authors of the last century is quite unacceptable, because it contradicts much geological data.

In thus expressing his ideas the author is not definitely convinced in their correctness, however, from the material which he posseses the drifting theory of the continents is more acceptable than any other theory. Only an examination of all elements of the flora and fauna of New Zealand can furnish a firm basis for a correct interpretation, so we are still very far from this goal. However, a working theory is useful for progress of our knowledge.

Subfamily *PANOPINAE*

Genus APSONA Westwood

1876. Ent. Soc. London, Trans. 1876: 510.

Type species: *A. muscaria* Westwood.

Westwood writes:

Genus novum *Panopi* et *Lasiae* affine, differt antennis apice longe aristatis; proboscide longitudine mediocri, cellulis duobus posticis basi a venulâ unicâ basali pedicellatis.

Caput rotundo-transversum; oculis maximis antice conjunctis, setosis. Ocelli 3 in tuberculum parvum positi, verticales. Antennae in medio faciei insertae, articulis duobus basalibus parvis, ultimo basi elongato-ovato, apice in setam longam tenuem producto. Proboscis elongata, thoracis longitudine, apice bilabiato. Alae venis fere ut in *Lasiâ* et *Panope* dispositis, cellulâ autem curvatâ apicali e venulâ tertiâ postcostali pone cellulam angustam mediam discoidalem emissâ; cellulâque triangulari etiam basi pedicellatâ. Pedes graciles; abdomen fere globosum. Color metallicus.

Apsona muscaria Westwood

1876. Ent. Soc. London, Trans. 1876: 510. (pl. 5, fig. 2).

Westwood writes:

Valde convexa, nitida, sublente tenuissime coriacea, cupreoviridis, luteo-pubescens, proboscide et antennis nigris, pedibus luteoflavis, femoribus in medio obscurioribus; alis hyalinis, venis nigris.

Long. corp. lin. 4; probosc. lin. 2; expans. alar. lin. 8½.

Habitat in Novâ Zelandiâ. In mus. Hopeiano Oxoniae.

Body metallic green, shining. Legs (excluding coxae), halteres and anterior spiracles yellow, proboscis brown. Whole body, including eyes, with very dense, erect, yellowish hairs. Squamae alaris transparent, with yellow rim and also yellowish-haired. Empodium and pulvilli of same size, form and colour, yellowish. Wings with a very well developed venation, only the branches of M towards the hind margin evanescent. Alula absent. Anal cell long, petiolated. Lower basal cell M is distinctly narrower and longer than the upper basal cell R. Fourth posterior cell (subdiscal) is triangular, petiolated at base, connected to the hind margin by a short vein. Discal cell extremely long, slightly broadened towards the apex. Both branches of R_4 and R_5, short-petiolated. First posterior cell is extremely long, the cross-vein r-m is beyond the apex of the discal cell, another cross-vein is situated at its base.

The author has seen specimens from Arthur's Pass, New Zealand, 23. i. 1928 (A. Philpott).

A comparison with *Eulonchus smaragdinus* gives many details of this species, which were absent in the short description of Westwood.

1. Proboscis in *Eulonchus* is extremely long, in normal position directed backwards under the body and protruding beyond the apex of abdomen on the side of abdomen, in *Apsona* it does not reach the apex of the abdomen. This character cannot be regarded as generic because the length of proboscis is variable in Diptera in both sexes and individually rather strongly, so the structure of proboscis and palpi is quite similar in both species.
2. Head in *Apsona* is more declined than in *Eulonchus*, in which it has a nearly normal position in relation to the thorax.
3. Face in *Eulonchus* is turned downwards, in *Apsona* in oblique position.
4. Antennae in *Apsona* are inserted at a distance from the ocellar triangle, about as long as the latter, in *Eulonchus* nearly in the middle between the ocelli and the mouth.
5. Extremely fine strip separates the eyes above and below the antennae in *Eulonchus*, in *Apsona* they touch below the antennae.
6. Ocellar triangle is short, high, prominent in *Eulonchus*, in *Apsona* longer, broader and flat.
7. Occipital part of head in profile is very narrow above in *Apsona*, in *Eulonchus* it is rather broad.
8. In *Eulonchus* all tibiae on outer side have an acute prolongation of the edge, in *Apsona* the edge is nearly round.
9. Subdiscal cell is touching, basally, the lower basal cell in *Eulonchus*, in *Apsona* it is separated from the lower basal cell by a rather long petiole.
10. Tergites in *Eulonchus* with very short

yellowish hairs, in *Apsona* with long ones.

All these characters have a relative value but the striking similarity is quite dominating.

Apsona caerulea Brunetti

1926. Ann. and Mag. Nat. Hist. IX, 18: 581.

Brunetti writes:

Head. Eyes with long, dense, bright rufous-brown pubescence, apparently contiguous, but actually sufficiently separated to show a very narrow shining metallic blue space between them throughout, from the shining, almost blue-green frons bearing long, black, rather shaggy hair to the narrow shining black triangular frons. Antennae elongate, very slender, first joint very short, cylindrical, brown with a little grey dust; second much thicker, nearly as broad as long, subcylindrical, brown, with some stiff bristly hairs at tip; third very slender, pale yellow, nearly three times as long as second, basal half cylindrical, very much narrower than second joint, apical half elongate conical, narrowed at base, with long fine apical arista. Proboscis long, slender, *Lasia*-like, sheath bright shining metallic blue, much longer than full length of body, black. Occiput metalic blue, with long shaggy dark grey hair.

Thorax shining metallic blue with green reflections and long, rather coarse, blackish hair, more greyish towards sides. Scutellum more than twice as broad as long, with concolorous pubescence, hind margin gently curved, with more whitish pubescence.

Abdomen shining metallic blue, with rather long, fine, black pubescence. Two peculiar and conspicuous small patches of much denser black hair on discs of second, third, and fourth segments, well separated. Belly shining violet, with black pubescence.

Legs. Femora and tibiae shining dark brown, with a little fine black pubescence; tarsi yellowish (except the black tips), with yellowish pubescence, which latter also occurs on inner sides of tibiae on about apical half.

Wings quite clear yellowish grey; venation normal except fork of third vein much more upturned than in type-species, and fourth posterior cell almost contiguous at its pointed base with tip of second basal cell. All endings of fourth vein not reaching wing-margin. Alar squamae yellowish, bare, black-fringed; thoracal squamae ferruginous, with rather long shaggy depressed whitish hair. Halteres concealed.

Length 7½ mm., proboscis 9 mm.

A unique of uncertain sex in the British Museum, Minas Geraes, Brazil (Rogers), from the Saunders collection. The only previously known species is *muscaria*, Westw., the genotype from New Zealand.

Subfamily *PHILOPOTINAE*
Genus HELLE Osten-Sacken

1896. Ent. Monthly Mag. 32: 16.
Hutton, 1901. New Zeal. Inst. Trans. 33: 28.

Type species: *H. longirostris* Hudson.

Osten-Sacken writes:

Eyes glabrous, contiguous above the antennae as far as the ocellar triangle. Three ocelli. Antennae inserted about the middle of the head (seen in profile), very small; second joint incrassate at the base and attenuated beyond it in the shape of an arista-like prolongation. Proboscis elongate. Hind part of the head swollen. Thorax gibbous; prothoracic lobes contiguous along a rather long suture, on both sides of which they expand hindwards, so that the hind margin of the prothorax shows a deep emargination. Neuration almost complete; a single submarginal cell; an elongate, somewhat pentagonal discal cell; four posterior cells, incomplete in consequence of the post-discal veins not reaching the margin; two distinct basal cells; the anal cell closed long before the margin, its petiole stunted a little before reaching the margin. Tegulae large. Legs smooth, without spurs; tarsi but little shorter than the tibiae; joints three and four are the shortest, both together nearly equal the first in length. Three pulvilli. Abdomen oval, with the first segment short; the five other dorsal segments longer and nearly of the same length, with coarctations at the incisures.

Hutton adds, "The neuration closely resembles that of *Megalybus pictus* Westwood, Trans. Ent. Soc. London, 1876, pl. v. fig. 4a."

KEY TO THE NEW ZEALAND SPECIES OF HELLE

1. Larger species, length of body about 7 mm. Prothoracic plates not touching, always separated by one rather broad furrow. Yellowish-red species, with black median longitudinal stripe on mesothorax and two lateral ones, abbreviated in the presutural area . . . . . **rufescens** Brun.
   Smaller species, about 3–4 mm. in length. Brown species with mesonotum uniformly coloured, no darker longitudinal stripes 2
2. Thorax deep blue-black. Ocelli distinct . . . . . **megalyboides** Brun.
   Thorax dull blackish with a slight aeneous tinge . . . . . **longirostris** Hudson*

* Hudson has not described this species, the coloured illustration in his book is not good, the insect is unrecognisable. The first author who recognised the right position of the species and has described it was Osten-Sacken, 1896.

Helle rufescens Brunetti

1926. Ann. and Mag. Nat. Hist. IX, 18: 572.

Brunetti writes:

Head mainly as in *longirostris*, but occiput much narrower and front ocellus indefinite or absent.

Thorax bright brownish red, hind corners of prothoracic plates, which do not quite touch in the median line, narrowly pale yellow; dorsum with three contiguous broad black stripes; the middle one beginning on anterior margin of mesothorax, where it broadens a little, continuing to hind margin of dorsum, where it is considerably narrowed. Outer stripes beginning just in front of wing-base and ending, narrowed a little, on hind margin. Scutellum very globular, a little blackish on underside at base; metanotum more or less blackish.

Abdomen reddish, concolorous with thorax; a blackish, elongate, transverse spot with indefinite outline each side of median line on hinder half of each segment, more distinct on third, fourth, and fifth segments; base of each segment from fourth onwards more or less black and a little contracted. A fine microscopic whitish pubescence over all dorsum. Venter concolorous reddish with dorsum, a little blackish transversely at base of each segment.

Legs brownish yellow; femora, except tips for a short distance, obscurely brown; tips of tarsal joints narrowly brown.

Wings yellowish grey; venation as in *longirostris*, except for an extra cross-vein between third and fourth veins above tip of discal cell. All veins distinct. The elongate thickening of first vein yellowish brown, much less conspicuous than in *longirostris*. Squamae obscurely whitish, the yellow clubs of the halteres visible through them, their margins distinctly yellow.

Length 7 mm.

Type from Buller River, New Zealand, 29. xii. 1918 (G. V. Hudson, no. 47h). A second specimen labelled ?Buller Riv., N. Zeal. (collector's no. 47g), also collected by Hudson. Both in the British Museum.

The author has seen specimens from the following localities: New Zealand: 2♂♂, 20. xii. 1921, Mt. Arthur Tl., 4,500 ft. (A. Tonnoir); 1♂, 6. xi. 23, Nelson (A. Tonnoir); 1♂, 9. ii. 1921, Dun Mt., 3,000 ft. (R. J. Tillyard).

In one of the specimens from Mt. Arthur the additional vein at the apex of the discal cell is quite absent in both wings. The specimen from Nelson has it on both wings, situated rather far beyond the apex of the discal cell. In the fourth specimen it is present only on the right wing in the same position. The second specimen from Mt. Arthur has the additional vein exactly above the apex of the discal cell.

The occipital part of the head in profile is very narrow, about as broad as the anterior tibiae. In other species it is broader than the femora and much broader when viewed from above.

Helle longirostris Hudson

1896. Manual of New Zealand Entomology, 56, tab. vii, fig. 4. (Acrocera).

Osten-Sacken, 1896. Ent. Monthly Mag. (ser. 2, vii), 32: 16.

Brunetti, 1926. Ann. and Mag. Nat. Hist. IX, 18: 571.

Brunetti writes:

Redescription.—Head dull blackish; eyes quite bare, closely contiguous from just below small vertex to frontal triangle; latter bright orange. Ocellar triangle flush with eyes; ocelli brown, front ocellus small, distinct, the other two larger and less well defined. Antennae dark brown; face blackish; proboscis one and a half times as long as height of head, pale yellowish above, dark brown below, the basal sheath moderately dark brown, shining. Occiput very broad above, narrowing gradually to lower part, the latter still broad, whole margin with microscopic whitish hairs.

Thorax dull blackish, with a slight aeneous tinge, minutely punctate; outer margins of prothoracic plates and their hind corners more or less dull reddish yellow, sides and hind corners of dorsum, also pleurae and hind margin of scutellum similarly coloured, varying a little in intensity.

Abdomen dull blackish with a slight aeneous tinge, minutely punctate; hind margins of segments towards sides narrowly bright orange; extreme side margins of abdomen narrowly orange. Seen from in front, dorsum with rather dense, very short, fine, whitish pubescence. Venter black, hind margins of segments very narrowly orange, more or less interrupted. Genitalia mainly concealed.

Legs. Coxae and femora blackish brown, trochanters and tips of femora yellowish; tibiae and tarsi brownish yellow, dorsum of each tarsal joint blackish in middle; pulvilli yellowish, claws black.

Wings uniformly yellowish grey, all veins distinct; first vein with a spindle-shaped black thickened apical part; second and third veins practically parallel for their last two-thirds, third vein parallel with fourth vein as far as end of discal cell. An adventitious cross-vein sometimes occurs between third and fourth veins shortly beyond tip of discal cell, sometimes found in one wing only. No veins after third reaching wing-margin; fifth vein forming hinder side of discal cell for some distance, discal cell large; second basal cell longer than either first basal or anal. Squamae whitish, nearly transparent, margin barely obvious, through them can be seen the large yellow clubs of the halteres.

Length 3½–4 mm.

Three specimens in the British Museum appear to be this species. Wellington, New Zealand, 1. iii. 1910 (Capt. F. W. Hutton); Botanical Gardens, Wellington, 28. xi. 1906 (W. Wesché); Ngaio, N. Z., 21. xii. 1921 (G. V. Hudson, no. 306f). In the specimen captured by Wesché the adventitious cross-vein is present in the right wing only; in the one taken by Hutton it occurs only in the left wing; in the third specimen mentioned there is no trace of it in either wing.

This species was not described by Hudson, but he gave a coloured plate which simply portrays a blackish body, pale legs, unicolorous wings, with a venation which is not identical with that of *Helle*, but may be regarded as an indifferent copy of it. The apical thickening of the first vein certainly suggestive. Hudson sent a specimen of his species to Osten-Sacken, who described it (Ent. Month. Mag. (2) vii, p. 17, 1896), and through the inadequacy of Hudson's plate the authorship of the species should count to Osten-Sacken, though I do not suggest any alteration now. A specimen in the British Museum under this name, by whom identified I do not know, cannot be true *longirostris* and I describe it herein as *rufescens*.

D. Miller in his Catalogue of the Diptera of the New Zealand sub-region, (1950: 75), has transferred this species from the genus *Helle* to *Oncodes;* the reason for this is not stated. The genus *Helle* belongs to the subfamily *Philopotinae* and the transfer of this species to another subfamily *Oncodinae* cannot be accepted.

The type of *H. longirostris* apparently was not fixed and can be regarded as lost. Therefore the first recognisable description of Osten-Sacken should be regarded as the only valid one.

Helle megalyboides Brunetti

1926. Ann. and Mag. Nat. Hist. IX, 18: 573.

Brunetti writes:

Head mainly as in *longirostris*. Ocellar triangle flush with the eyes, wholly occupied by the three brownish ocelli, which are more distinct than in the other two species. Frontal triangle bright orange, a little prominent, below it a pair of whitish pubescent spots; antennae moderately light brown. Face black; proboscis one and a half times as long as height of head, pale yellow, tip blackish, sheath brownish yellow. Occipital margin very broad (as in *longirostris*), but sloping away rapidly from hind margin of eyes, deep blue-black, finely punctate.

Thorax deep blue-black, finely punctate; prothoracic plates quite contiguous in median line; outer and hinder angles rather broadly brownish yellow, the same colour occuring on propleurae, around wing-bases, narrowly thence to the reddish-orange hind margin of scutellum.

Abdomen of six segments, separated by deep incisions, deep blue-black, finely punctate, traces of orange narrowly towards sides of hind margins of segments. Whole dorsum of abdomen and venter with very short whitish pubescence, barely visible except from in front. Genitalia concealed. Whole abdomen in general outline (except for the deep inter-segmental incisions) subcylindrical, slightly narrowing from base to tip.

Legs. Coxae and femora black, tips of latter rather broadly but indefinitely yellowish. Tibiae and tarsi brownish yellow, dorsum of tarsal joints brownish except at base.

Wings yellowish grey; venation as in *longirostris*, the additional cross-vein between third and fourth veins present. Clubs of halteres yellow; squamae obscurely whitish, about basal half of disc (except margin) blackish brown; margins not differently coloured.

Length nearly 4 mm.

Described from two specimens in the British Museum: Wilton's Bush, Wellington, New Zealand, 27. xi. 1921 (G. V. Hudson, "206" (♀), type; the second example labelled simply "New Zealand" (G. V. Hudson, "206a" and "47d").

The author has not seen this species. From the description by Brunetti it is evident that it is very closely related to *H. longirostris*. There is a possibility that it is only the other sex of *H. longirostris*.

Subfamily *ONCODINAE*

Genus ONCODES Latr. 1796

KEY TO THE NEW ZEALAND SPECIES OF ONCODES

1. Hairs on whole body yellowish . . . . . **O. consimilis** Brun. (♂, ♀)
   Hairs on whole body black, or dark brown 2
2. Abdomen black . . . . . **O. nitens** Hutt.
   Abdomen dark-brown, with narrow yellowish margins on tergites . . . . . **O. brunneus** Hutt.

Oncodes brunneus Hutton

1881. Cat. Dipt. New Zeal. p. 24; 1901. New Zeal. Inst., Trans. 33: 29.

Maskell, 1888. New Zeal. Inst., Trans. 20: 106–108, pl. 10 (Henops).

Brunetti, 1926. Ann. and Mag. Nat. Hist. IX, 18: 593–594.

Maskell writes:

Flies (fig. 1) rather large, but squat-looking and heavy; motions very slow. Thorax much elevated, the head being bent down beneath it so as not to be visible when the insect is viewed from above. Abdomen round and swollen, wider than the thorax but seeming as if cut off short, the posterior extremity being turned under; there are six segments on the abdomen. *Colour* dark brown, almost black, on the thorax, with short yellow hairs; abdomen dark brown, with a yellow band marking each segment; head black; Wings hyaline; halteres yellow. The winglets are very large and scale-like. *Eyes* very large, compound, occupying all the upper part of the head, but not highly convex (fig. 2). *Antennae* (fig. 3) inserted in front, between the eyes; two-jointed, both joints very short; the style is very long, inflated near the base, narrow in the shaft and slightly dilated at the tip, where there are two short bristles. *Proboscis* (fig. 2) very short, almost obsolete, conical; placed so much beneath the down-turned head as to be extremely difficult to detect. *Feet* (fig. 5) long and slender; tarsus five-jointed; claw double (fig. 6) with three pulvilli. *Wings* (fig. 4) with brown costal and subcostal veins; discoidal cell open; cubital cell large; and postical vein appears to have a branch almost if not quite disconnected. Length of the body, in the usual postion, nearly $\frac{1}{5}$ inch.

Hutton, 1901, writes:

Head black; antennae pitch-brown. Thorax pitch-brown, with scattered tawny hairs. Abdomen brown, the posterior margin of each segment tawny. Legs pale-brown. Wings hyaline; the costa and second longitudinal vein brown. Length, 5–6 mm.; wing, 5–7 mm.

Hab. Otago (F.W.H.); Wairarapa (Maskell); Auckland (Broun).

Brunetti writes:

A short series in the British Museum from New Zealand, some labelled Wellington, 3. ii. 1911 (Capt. F. W. Hutton); Christchurch, Ohakune, v. 1922 (J. W. Campbell), others with no closer data.

A further series from New Zealand amongst the unnamed material in the British Museum have nearly or entirely clear wings, and the legs showing much variation, being in individuals entirely and quite black, in others shining brown varying in intensity and extent, in others again with the tibiae all brownish yellow. The data are as follows:—Wilton's Bush, Wellington, 28. xi. 1921; 6. xii. 1920; Karori, Wellington, 28. i. 1917; 16. ii. 1920; Gollans Valley, 24. xii. 1921 (all G. V. Hudson). Ohakune, 1922–23 (T. R. Harris). The specimen from Gollans Valley has a pale irregularly-shaped spot of some size, but with indefinite outline towards each side margin on the third segment.

The author has seen only one specimen: 1 ♀, 23. xii. 1924, Dun Mt., 3,000 ft., N. Z. (A. Philpott).

Oncodes consimilis Brunetti

1926. Ann. and Mag. Nat. Hist. IX, 18: 603.

Brunetti writes:

Considerably like *O. basalis* Walk. The pubescence of the thorax is more yellowish, that of the abdomen is distinctly longer, rather conspicuously whitish, the clear-cut yellow hind margins of the segments being quite bare (as is the case also in *basalis*). The first and second abdominal segments are all black, the third, fourth, fifth, and sixth mainly blackish brown on more than the basal half of each, the remaining portion paling to a bright yellowish brown; the black spots at the sides of the segments are less clearly demarcated, larger, more triangular, and almost united to the blackish-brown basal band. The femora are much more slender in form, brownish yellow, indistinctly darker distally; the tibiae brownish yellow, the tarsi mainly black but first joint brownish yellow on basal half or more.

Length 6 mm.

A single specimen from Mount Ruapehu, New Zealand, 4,000 ft., Jan. 1922 (G. V. Hudson).

Unique type in British Museum.

Apart from the first and second abdominal segments, which are wholly black in both species (except for the whitish hind margin of second segment in each), the ground-colour of the rest of the abdomen in *consimilis* is blackish brown, shading into brownish yellow posteriorly; but in *basalis* it is bright brownish yellow, with the black spots clearly cut on third and fourth segments. In the type of *basalis* the pubescence of the thorax and abdomen is more yellowish, that of the abdomen much shorter than in *consimilis*; the black in the femora is on the basal half only and sharply defined, the femora themselves stouter and more uniformly cylindrical; the tibiae uniformly bright orange and the tarsi wholly black from base to tip. The wings in *consimilis* are absolutely colourless and the squamae nearly as clear, although not actually transparent; in *basalis* the wings are yellowish grey, the squamae obscurely whitish.

The author has seen specimens from the following localities: 2 ♂♂, 30. xi. 1921, Khandallah, N. Z. (A. Tonnoir); 1 ♂, 1 ♀, 2. xii. 1921, Wilton's Bush, N. Z. (A. Tonnoir); 1 ♂, 5–7. i. 1922, Dun Mt., 3,000 ft., N. Z. (A. Tonnoir).

Oncodes nitens Hutton

1901. New Zeal. Inst., Trans. 33: 29.

(Henops).

Hutton writes:

> Shining black, with black hairs on the thorax and abdomen. The tibiae, except their bases, the tarsi, except the last joint of each, and a spot on each side of the second and third abdominal segments, tawny. Wings hyaline. Length, 5–6½ mm.; wing, 4½–5 mm.
>
> Hab. Auckland (Broun); Wellington (Hudson).

SUMMARY

To the present time no review of the New Zealand Cyrtidae has been published. Although the cyrtid fauna is very meagre (only 3 genera [3 subfamilies] with 7 species), it is very difficult to identify them, because the descriptions lack the completeness required by modern systematics. The author has given all the necessary additional data to bring our knowledge up to date, and also hopes to stimulate the discovery of additional species.

The comparison of the New Zealand cyrtid fauna with that of Australia and America, shows that it is much closer to the American than to Australian fauna. The cause of the absence of some families of Diptera was also discussed.

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Two New Spongicolous Amphipods (Crustacea) From California[1]

J. Laurens Barnard[2]

Two new species of gammaridean Amphipoda, described herein, were collected from spiculated horny sponges in Newport Bay, California. One of these species is of special interest for it probably derives its nourishment from the sponge tissues while the other may be only a facultative inhabitant of spongocoels. Arndt (1933) may be consulted for an interesting discussion and review of other amphipods inhabiting sponges, most of which take refuge in spongocoels for protection and easy access to minute food particles other than the host's tissues.

The writer is indebted to the Allan Hancock Foundation for use of laboratory space and equipment and to Dr. John L. Mohr and Mr. R. H. Linsley for procuring the animals.

Family *LEUCOTHOIDAE*

Leucothoides pacifica, new species

Figs. 1, 2*e*, *h*, *n*

DESCRIPTION OF MALE: Head with a short, blunt rostrum, lateral lobes broadly rounded, lower anterior corner rounded; eyes large, composed of a few large facets.

Antenna 1 longer than 2, articles of peduncle successively slightly shorter, flagellum slightly shorter than peduncle, with 10 articles; accessory flagellum minute, biarticulate.

Antenna 2 with article 5 of peduncle shorter than 4, flagellum with 4 articles, shorter than article 5 of peduncle.

Mandible with 10 spines in spine row, palp with one article bearing 2 terminal setae; molar absent.

Maxilla 1 with 7 spines on outer plate and 3 on distal end of palp article 2. Maxilla 2 sparsely setose.

Inner plates of maxilliped coalesced at base only, not reaching to base of outer plates, each distal edge armed with 3 spinules; outer plates conical, short, each armed with 2 spines.

Gnathopod 1 complexly chelate, coxa produced narrowly in front, articles 5 and 6 with the apposing edges minutely serrated; posterior edge of article 6 with several short, widely spaced spinules; distal end of process of article 5 with a long, blunt spine; article 7 minute, curved.

Gnathopod 2 with article 5 four fifths as long as 6, greatly produced and setose behind, article 6 not expanded distally, palm slightly oblique, convex, serrated irregularly, defined by 3 spines; article 7 stout, strongly curved, nearly as long as palm.

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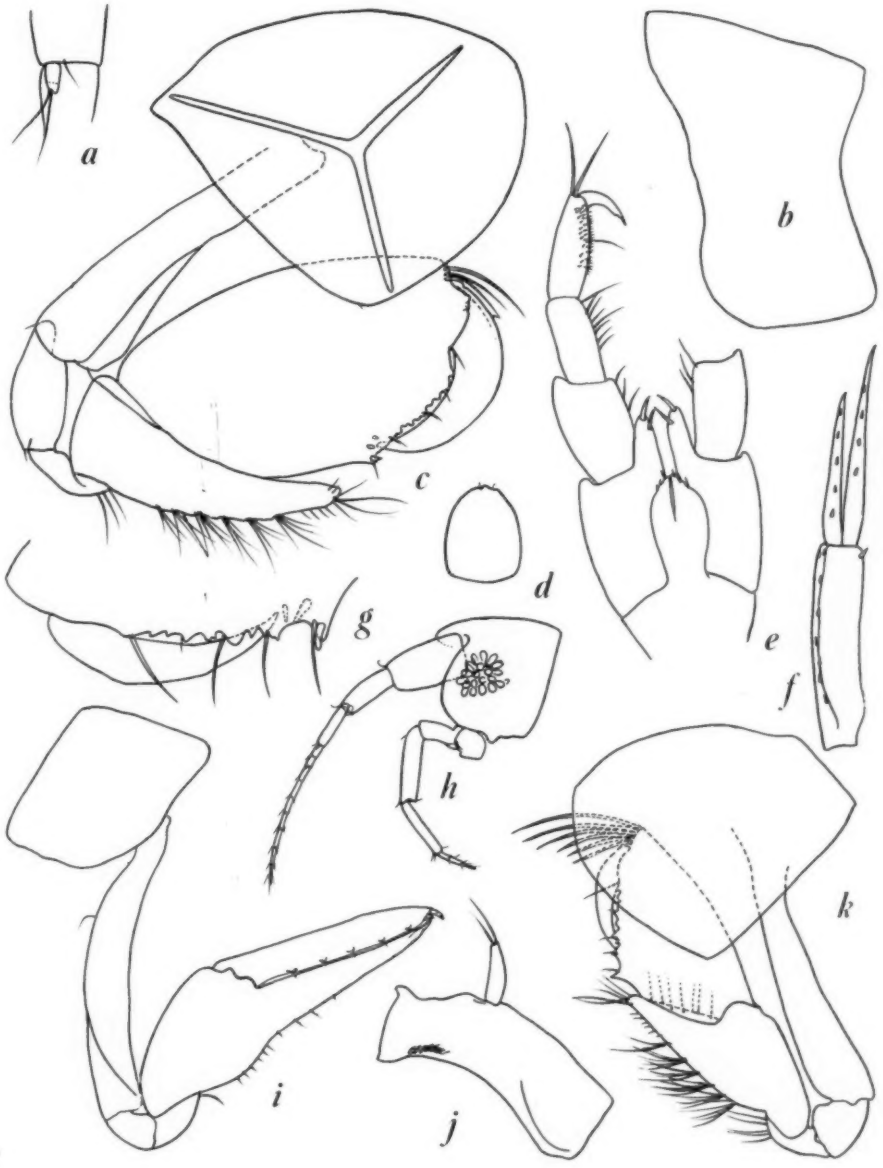

FIG. 1. *Leucothoides pacifica*, n. sp. Male, 4 mm.: *a*, accessory flagellum; *b*, pleon segment 3, left; *c*, gnathopod 2; *d*, telson; *e*, maxilliped; *f*, uropod 1; *g*, gnathopod 2, palm; *h*, head; *i*, gnathopod 1; *j*, mandible. Female, 4 mm.; *k*, gnathopod 2.

Peraeopods 1 and 2 equal in size. Peraeopods 3 to 5 successively slightly longer, second articles broadly expanded.

Uropods with outer rami shorter than inner, inner rami not longer than peduncles; uropod 1 longest, uropod 2 shortest. Telson similar to *Leucothoides pottsi* Shoemaker (1933).

Pleon segment 3 with posteroventral corner of epimera rounded.

FEMALE: Process of article 5 on gnathopod 2 relatively shorter than in male, palm very oblique, serrated, article 7 not stout.

HOLOTYPE: AHF No. 516, male 4 mm. in length.

TYPE LOCALITY: Ellis Boat Landing, Newport Harbor, California (on the south side of United States Highway 101A bridge crossing the channel leading to upper Newport Bay), July 27, 1951, collected by Dr. John L. Mohr, 13 specimens examined.

MATERIAL EXAMINED: Ellis Boat Landing, November 29, 1953, formalin washings of sponges, coll. R. H. Linsley, 20 specimens; dock of Fun Zone Boat Co., Palm Avenue at Bay Front Street, Newport Beach (on bay side), November 29, 1953, formalin washings of sponges, coll. R. H. Linsley, 26 specimens.

REMARKS: This species differs from *Leucothoides pottsi* Shoemaker (1933) from Tortugas, Florida, by: (1) the convex palm of the male second gnathopod; (2) the stout seventh article of the male second gnathopod; (3) the rounded lower anterior corner of the head; (4) the long peduncle of uropod 1.

The figure of the male second gnathopod shows one of the sponge spicules drawn to the same scale and superimposed on the coxal plate. This particular spicule was removed along with others from the "brood pouch" region of the male. This type of calcareous spicule indicates that some of the specimens obtained by formalin washings were from the smaller calcareous sponges present in some samples.

Family *ANAMIXIDAE*

Anamixis linsleyi, new species
Fig. 2*a–d, f–m, o–w*

DESCRIPTION OF MALE: Head fused with first peraeon segment so that each is not freely movable, but lines of articulation not obscured; rostrum blunt; eyes large, composed of few facets; lateral lobes not produced; front of head between antennae bears a low but sharp carina.

Antenna 1 longer and stouter than 2, as long as head and first 3 peraeon segments; accessory flagellum minute, barrel-shaped, armed with 2 setae; articles of peduncle successively shorter, primary flagellum not as long as peduncle, composed of 9 to 11 articles.

Antenna 2 with article 5 shorter than 4, flagellum shorter than article 5 of peduncle, composed of 4 to 5 articles.

Mouth parts degenerated: on the underside of the head is a single, thin, pointed lamella, possibly representing the fused mandibles. Maxillae 1 and 2 obsolete.

Maxilliped with inner plates fused and short, in some larger specimens (5 mm.) completely obsolete; outer plates obsolete; article 5 of palp slender, curved, armed on inner edge with short hairs.

Gnathopod 1 complexly chelate, small, the coxal plate produced forward conically and partially concealed by the large second coxa; inner edge of article 6 serrulate, article 7 small, spinuliform; chela of article 5 retruse and blunt at apex.

Gnathopod 2 complexly chelate, article 5 produced forward into a conical appendage nearly as long as article 6; palm not distinct from hind margin, armed with several cusps, the distal one the longest; article 7 closing on process of article 5, inner edge with 3 cusps, the distal one armed with 2 spinules.

Peraeopods as figured.

Uropods 1 and 2 with inner rami longer than outer, both armed on upper edges with spinules. Uropod 3, rami subequal in size.

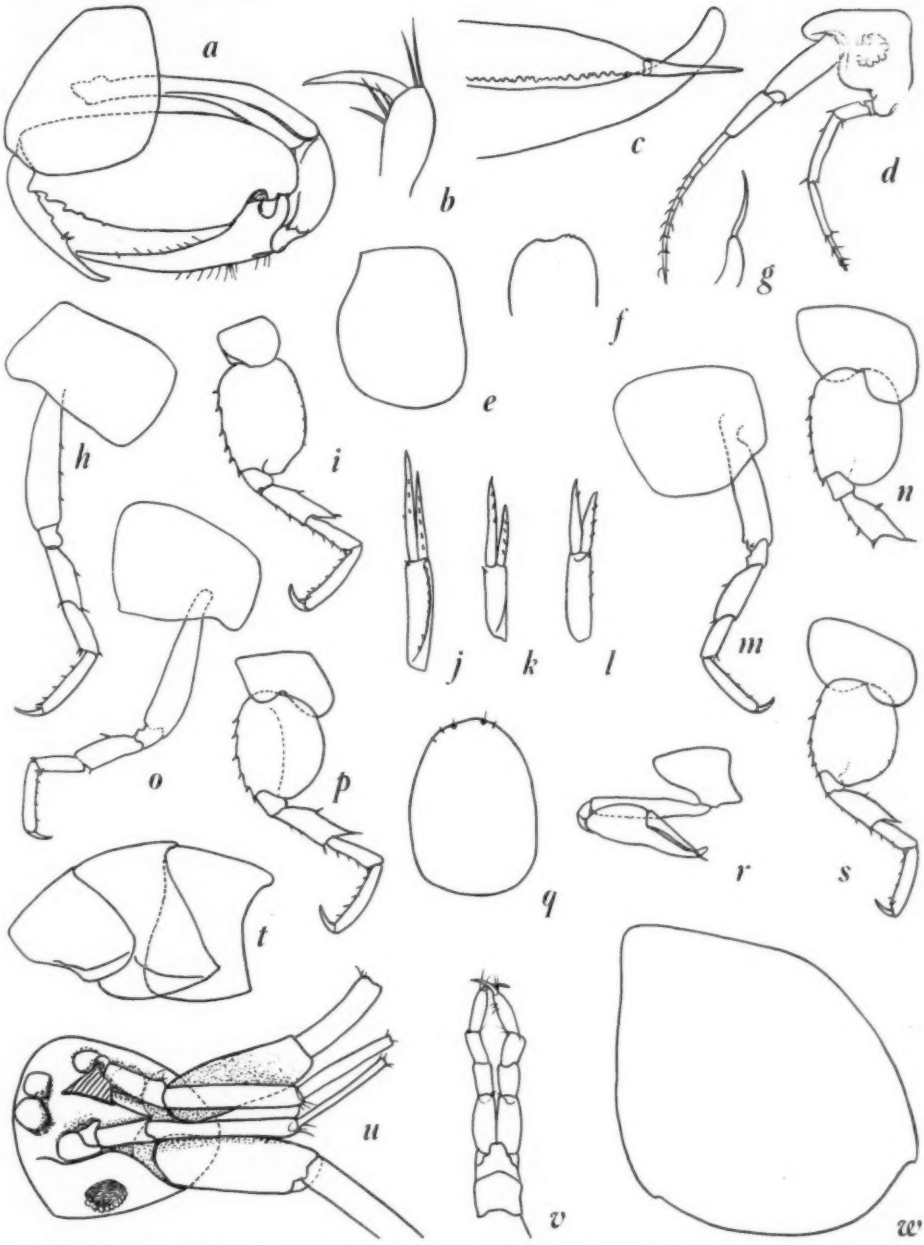

FIG. 2. *Anamixis linsleyi*, n. sp. Male, 4mm.: *a*, gnathopod 2; *b*, end, maxilliped palp; *c*, end, gnathopod 1; *d*, head; *f*, maxilliped, inner plates; *g*, finger, gnathopod 1; *i*, peraeopod 5; *j–l*, uropods 1–3; *m*, *o*, *p*, peraeopods 2, 1, 3; *q*, telson; *r*, gnathopod 1; *s*, peraeopod 4; *t*, pleon segments 1–3; *u*, head, ventral; *v*, maxilliped; *w*, coxa 2. *Leucothoides pacifica*, n. sp. *e*, Coxa 4; *h*, peraeopod 1; *n*, peraeopod 3.

Telson simple, linguiform, apex rounded, armed with several groups of setules.

Pleon segment 3 with posterior edge of epimera straight, posteroventral corner quadrate.

FEMALE: Two specimens possibly carrying 2 to 3 shrunken embryos each were dissected. No brood plates were evident and no sexual differences were observed.

HOLOTYPE: AHF No. 531, male 5 mm. in length.

TYPE LOCALITY: Ellis Boat Landing, Newport Harbor, California (on the south side of United States Highway 101A bridge crossing the channel leading to upper Newport Bay), November 29, 1953, from a formalin washing of sponges attached to floating dock, collected by R. H. Linsley, 7 specimens examined.

MATERIAL EXAMINED: Ellis Boat Landing, July 27, 1951, coll. Dr. John L. Mohr, 1 specimen; dock of Fun Zone Boat Co., Palm Avenue at Bay Front Street, Newport Beach (on bay side) November 29, 1953, formalin washings of sponges, coll. R. H. Linsley, 2 specimens.

REMARKS: This species differs from *Anamixis hanseni* Stebbing (1897), described from the West Indies, by the stouter sixth article of gnathopod 2 and a different configuration of the palmar teeth. The coxa of gnathopod 2 is narrower (as measured from front to back) and article 7 is more slender than in *A. hanseni*. The apex of article 5 of gnathopod 1 is blunt and not tipped with a spine as in Stebbing's species.

A. linsleyi differs from *Anamixis stebbingi* Walker (1904), described from Ceylon, by the shape of the second coxa, by the presence of cusps on the palm of gnathopod 2, and by the lack of diverging ridges on the second article of peraeopod 5.

The writer agrees with Stebbing (1897) that the structure of gnathopod 1 is homologous to that found in the genus *Leucothoe;* Walker (1904) stated that article 4 (the third article under his system of numbering) was obsolete. His species of *Anamixis* lacked the spine-like finger on article 6, thus leading to his statements:

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Variation in Egg and Larva Production of the Anchovy, *Stolephorus purpureus* Fowler, in Kaneohe Bay, Oahu, during 1950–1952[1]

ALBERT L. TESTER[2]

INTRODUCTION

A SMALL ANCHOVY known locally as the nehu is the principal baitfish used in Hawaii for catching skipjack (*Katsuwonus pelamis*) by live-bait fishing methods (F. C. June, 1951). This baitfish, which is taken commercially by nightlight methods after dark or by surround net in the daytime, occurs in quantity only in a few localities on Oahu, e.g., Pearl Harbor, Honolulu Harbor, Ala Wai Canal, and Kaneohe Bay, all of which are shallow, relatively turbid, and in part brackish. These bays and inlets appear to support separate populations (Tester and Hiatt, 1952). As the supply of nehu comprising the populations appears to fluctuate both seasonally and annually, it is of interest and importance to investigate the causes. One possible factor, variation in egg and larva production, is dealt with here for one population, that of Kaneohe Bay, over a period of 24 consecutive months in the years 1950, 1951, and 1952.

Pertinent information on the spawning habits of the nehu, nature of the eggs and larvae, and the larval growth rate has been given by Tester and Yamashita (1950), Tester (1951), and Yamashita (Ms.). Briefly, the nehu is a pelagic spawner, spawning takes place (in Kaneohe Bay) mostly from 10:00 P.M. to midnight, the bluntly ovoid eggs hatch within about 24 hours or less, the typically clupeid, filiform larva measures about 2 mm. at hatching and appears to have an initial growth rate of about 1.5 mm. per day. A more detailed description of eggs and larvae, including criteria for identification, is given by Tester (1951: 326–327).

Previous studies on the distribution of nehu eggs and larvae in Kaneohe Bay were conducted by Tester (1951) in 1949 and 1950. In these, four general surveys of horizontal distribution (in September, December, March, and June) were made, together with interim surveys of horizontal and vertical distribution. Among other things it was found that (a) spawning took place in all months which were sampled, and no particular spawning season could be defined from the data, (b) the eggs were present at all depths but with a slightly greater abundance towards the surface, (c) most of the eggs occurred within the southern sector of the bay (Fig. 1), (d) within the southern sector, there appeared to be a consistent peak of abundance of eggs in the vicinity of Stations 4 and 5 (between Coconut Island and Mokapu Peninsula), (e) within the southern sector, the larvae appeared to move in a clockwise direction around the bay as they increased in size. It was recommended that a specific sampling program be undertaken at or near Station 4 to investigate in more detail the temporal distribution of eggs and larvae. The recommended program, cur-

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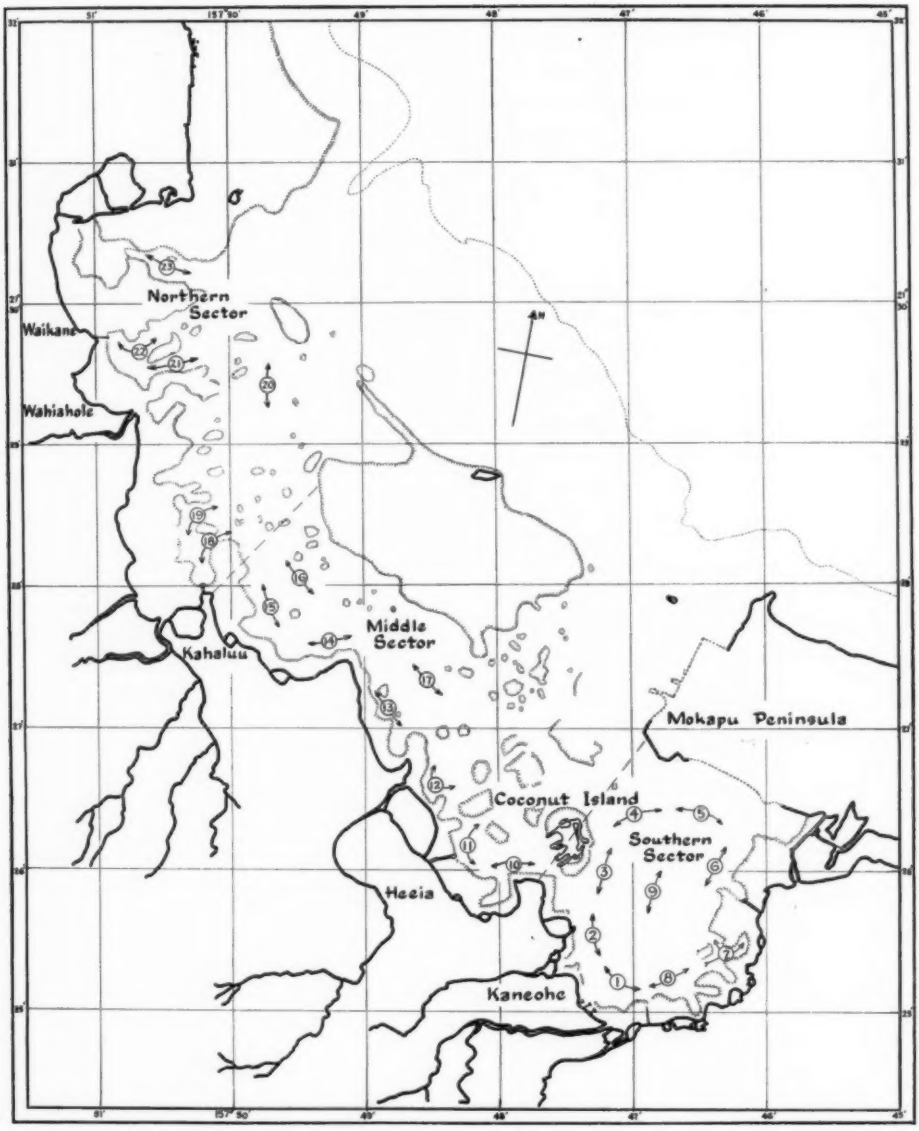

FIG. 1. Map of Kaneohe Bay showing the location of Station 4 (between Coconut Island and Mokapu Peninsula) with respect to the 23 stations sampled in a previous investigation.

tailed in some aspects and expanded in others, was started in 1950 and the data obtained form the basis for the present paper.

Acknowledgments

The investigation could not have been undertaken with efficiency without the specialized knowledge and ever-willing cooperation of Mr. Zukeran, skipper of the University's research vessel "Salpa." He assumed the responsibility of locating the sampling stations and of supervising the sampling procedure. Assistance by several graduate students of the University of Hawaii in field work and particularly in sorting plankton hauls in the laboratory, in counting nehu eggs and larvae, and in measuring fish is also gratefully acknowledged. These included Miss Tetsuko Fujita, Mr. Michio Takata, Mr. Royden Ikeda, and Mr. Austin Pritchard.

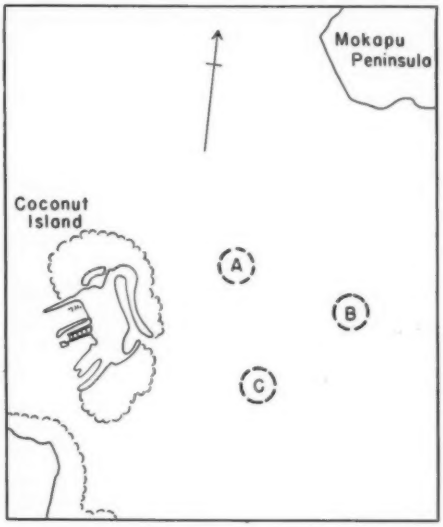

FIG. 2. Map showing the location of Substations A, B, and C at Station 4.

METHODS AND MATERIAL

Eggs and larvae were collected with specially constructed plankton nets having a mouth opening of 50 cm. and an overall length of 2 meters. They were modeled after the Hensen egg net, i.e., the diameter expanded to 75 cm. over a distance of 30 cm. back of the mouth, and then contracted in a cone with a 9 cm. diameter at the cod end. The forward expanding part was made of light canvas; the after conical part was made of No. 40 mesh, xxx grit gauze (aperture 0.47 mm.). An Atlas current meter was suspended in the center of the mouth by three wire supports equipped with turnbuckles. A cod end, also of No. 40 mesh grit gauze, 30 cm. in length and 9 cm. in diameter, was fastened to the end of the net by a detachable net band.

Sampling was confined to the vicinity of Station 4, located between Coconut Island and Mokapu Peninsula (Fig. 2) where as already indicated, previous work had shown a fairly consistent peak of abundance of nehu eggs (Tester, 1951: 336). Three substations (A, B, and C) were chosen at the apices of an equilateral triangle such that they were approximately 800 meters apart. Their positions were fixed by reference points on shore so that they could be located with reasonable precision on each trip.

Hauls were made twice a week, usually on Tuesday and Friday or on Monday and Thursday, starting August 31, 1950 and ending September 2, 1952. The sequence was interrupted only in two weeks when the "Salpa" was out of commission, and only one haul per week was made. On two occasions when the "Salpa" was in drydock, the hauls were made from a 24-foot plane personnel boat, but the methods and procedures were essentially similar to those used with the other vessel.

On each trip to Station 4, one 5-minute haul was made at each of the three substations, following a circular course with a diameter of about 300 meters. The circular rather than straight line course was chosen in order to keep the sampling within the presumed area of egg concentration and to avoid a bias

associated with direction and distance of haul (Tester, 1951: 332).

Each haul was made in precisely the same manner. The current meter was read; the net was lowered over the side; the ship's speed was increased from 0 to about 2 to 3 knots so that the upper edge of the mouth of the net was towed about 15 cm. below the surface of the water at a distance of about 25 meters astern. During the first haul in each set of three, the temperature was read to the nearest tenth of a degree (C.) from a freshly-scooped bucket of sea water, and a sample of sea water was taken for later chlorinity determination in the laboratory. At the end of exactly five minutes, the ship was stopped, the net was hauled alongside by hand, the current meter was re-read, the net was thoroughly washed from the outside with a power hose, it was hauled aboard, the cod end was removed and the contents placed in a quart jar with the usual care in rinsing, washing, etc. The jar was then labelled and formalin was added to make a solution of approximately 10 per cent.

In the laboratory, the plankton was placed in Petri dishes, sorted by eye and by low power dissecting microscope, and all nehu eggs and larvae were removed and counted. The larvae were subsequently checked for correct indentification under higher magnification and were measured to the nearest 0.1 mm. from the tip of the closed lower jaw to the base of the tail, using an ocular micrometer. Chlorinity of the water samples (p.p.m.) was determined by the Mohr method.

The Atlas current meters were standardized by determining the number of revolutions made in towing them at slow speed (about 3 knots—equivalent to about 3.7 revolutions per second) back and forth over a known distance between two buoys. There was close agreement between the calibration of the two meters, one of which was used for about 18 months and the other for the remaining 6 months. Calibration was undertaken but once rather than at intervals during the period of use. It is believed that this negligence led to no great error as (a) the meters were kept oiled, (b) the jewel bearings remained intact, and (c) there was no indication of a progressive change in the number of revolutions per 5-minute haul over the period of use.

As the hauls were standardized in time, the variation in volume of water strained from haul to haul was relatively small. Adjustment of the egg counts to a standard volume of water (100 cubic meters—a rough average of the actual volume strained per haul) was made, although it did not greatly alter the counts nor influence the major conclusions drawn from unadjusted data. The adjustments were made according to the following formula which is similar to that of Ahlstrom (1953: 6):

$$E_s = \frac{100\,E}{R.a.p.} = \frac{1{,}369.072\,E}{R}$$

where E_s is the number of eggs adjusted to a volume of 100 cubic meters of surface water;

E is the number of eggs per haul;

R is the number of revolutions of the meter per haul;

a is the area of cross-section of the mouth of the net (0.19635 square meters);

p is the length of the column of water needed to effect one revolution of the meter (0.372 meters).

The adjustment was not made for the larva count as the numbers involved were small and in most cases remained unchanged when the adjusted values were rounded to the nearest whole number. The unadjusted data may be considered to represent the number of larvae per 100 cubic meters of surface water.

RESULTS

Variation with Substation

Adjusted egg counts at Substations A, B, and C ranged respectively from 0 to 1,661, 0 to 1,722, and 0 to 2,617, with grand arithmetic means of 60.6, 61.8, and 81.1 eggs per 100 cubic meters for the 207 sampling days

TABLE 1
ANALYSIS OF VARIANCE OF (TRANSFORMED) EGG AND LARVA COUNT OVER A TWO YEAR PERIOD

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F
Egg Count:				
Substations	2	0.6248	0.3124*	3.2
Days	206	416.5646	2.0222**	21.0
Error	412	39.6087	0.0961	—
Larva Count:				
Substations	2	0.0184	0.0092	0.2
Days	206	65.9477	0.3201**	6.4
Error	412	20.5733	0.0499	—

* P about 0.05; ** P less than 0.01.

over the 2 year period. In the basic adjusted data, the range (and hence the standard deviation) of the substation determinations was obviously correlated with the mean, indicating the need for a transformation of the data in order to apply tests of significance. A logarithmic transformation was used: $y = \log (x + 1)$ (Barnes, 1952: 65); this not only tended to decorrelate the standard deviation and the mean but also avoided the logarithm of zero.

The transformed data were analyzed according to two criteria of classification, substations and days, with the results included in Table 1. There are highly significant differences between the three geometric means for substations: A–6.36, B–7.94, and C–8.80. Apparently on the average, Substation C was located closest to the focus of abundance of eggs in the southern sector of the bay (Tester, 1951: 336). The large and highly significant variation between sampling days was anticipated, and reflects both erratic daily egg production and seasonal variation in spawning activity.

Larva counts at Substations A, B, and C ranged respectively from 0 to 62, 0 to 51, and 0 to 57, with grand arithmetic means of 2.66, 2.18, and 2.44 larvae per 100 cubic meters. As shown in Table 1, there were no significant differences between the geometric means for substations (A–0.97, B–0.92, and C–0.98) but, as in the case of the eggs, there were highly significant differences between the means for days.

The great decline in numbers between the egg and larva stage is worthy of note and will be referred to again. For the grand arithmetic mean the decline is from 67.8 to 2.4 (96.5 per cent) and for the grand geometric mean it is from 7.01 to 0.96 (86.3 per cent.)

Variation with Time

The logarithms of the adjusted egg counts were averaged for each sampling day and were plotted against time (the detailed graph is not reproduced). It was at once apparent that there was considerable variation in mean egg count between successive sampling days during certain months. For example, on June 5, 8, and 12, 1951, the geometric mean counts per 100 cubic meters were respectively 10.2, 607.0, and 21.2; on July 2, 5, and 9, 1951, they were 0.8, 537.4, and 288.0. It is possible that this large daily variation in egg count could be due to shifting of the focus of spawning to and away from the vicinity of Station 4. However, it seems more likely that it is due mostly to large daily variation in actual egg production and thus in spawning activity. If so, it would be of interest to discover the cause or causes.

Perusal of the data on temperature and salinity indicated that these factors per se were

not responsible for the variation in egg count between sampling days. It was apparent, without statistical analysis, that there was no significant relationship.

Attention was next directed to the possibility of lunar effects. On the basis of one series of samples taken in Ala Wai Canal during July, 1949, Tester and Yamashita (1950: 1) suggested that spawning activity might be related to the lunar cycle, with maximum spawning during the first quarter and minimum spawning during new moon. To investigate a possible lunar relationship, geometric means of the adjusted egg counts were calculated according to lunar days for the years 1950–51 and 1951–52. The data were then grouped according to phases of the moon. The geometric means for dark, first quarter, full, and third quarter were respectively 13.63, 18.20, 13.55, and 12.04 in 1950–51, and 4.53, 3.54, 2.61, and 2.66 in 1951–52. The differences in mean count between phases were neither statistically significant nor were they consistent during the two years. The present data yield no evidence of lunar periodicity in spawning. The cause or causes of the large variation between successive sampling days remains unknown.

Despite the large variation between successive sampling days it is evident from the data that spawning is seasonal in nature with a peak production of eggs during the summer months and a low production during the winter months. This is best illustrated by the geometric means per 100 cubic meters according to successive months as given in Table 2 and portrayed on a logarithmic ordinate scale in Figure 3A. Average production of eggs was highest during July, 1951, and next highest during August, 1952. It was relatively low during the winter months of 1950–51, and still lower during the winter months of 1951–52.

The seasonal march of egg production follows closely the seasonal march of temperature (Table 2), but this does not necessarily imply a dependent relationship. There is a

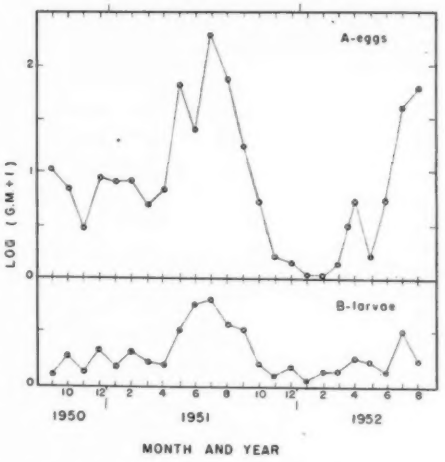

FIG. 3. Seasonal variation in the abundance (logarithm of the geometric mean plus one) of (A) eggs and (B) larvae.

marked difference in egg production between 1950–51 and 1951–52 (September to August, inclusive) with a geometric mean for the former of 14.12 and for the latter 3.27 eggs per 100 cubic meters. For the corresponding periods, mean water temperatures were 25.00° C. and 24.38° C. and mean chlorinities were 18.91 p.p.m. and 19.10 p.p.m., suggesting that higher temperatures and/or lower chlorinities were favorable for greater egg production. This possibility was investigated further using as variates the difference (with due regard to sign) between the means for the same months in the two years for temperature, chlorinity, and log egg count. Neither of the two partial regression coefficients (0.22 for log egg count and temperature; 0.06 for log egg count and chlorinity) was significant. The multiple correlation coefficient ($R = 0.41$) indicated that 83 per cent ($1-R^2$) of the total variation in egg count differences was unexplained by variation in the differences for temperature and chlorinity. It may be pointed out that this method of handling the data nullifies the seasonal trends. Although the results suggest that temperature may influence

TABLE 2
GEOMETRIC MEAN (G.M.) EGG AND LARVA COUNTS AND ARITHMETIC MEAN TEMPERATURES (°C.) AND CHLORINITIES (P.P.M.) ON A MONTHLY BASIS

MONTH AND YEAR	EGGS		LARVAE		TEMPERATURE	CHLORINITY
	Log (G.M. + 1)	G.M.	Log (G.M. + 1)	G.M.		
9/50	1.0223	9.53	0.1129	0.30	26.7	19.41
10/50	0.8504	6.09	0.2924	0.96	26.4	19.50
11/50	0.4855	2.06	0.1534	0.42	25.0	19.06
12/50	0.9485	7.88	0.3331	1.15	22.4	18.25
1/51	0.9234	7.38	0.1996	0.58	22.8	19.07
2/51	0.9289	7.49	0.3280	1.13	22.9	18.98
3/51	0.7028	4.04	0.2305	0.70	23.1	17.85
4/51	0.8264	5.70	0.1988	0.58	24.4	18.49
5/51	1.8148	64.30	0.5071	2.22	25.8	18.87
6/51	1.4007	24.20	0.7074	4.10	26.8	19.04
7/51	2.3013	199.10	0.7487	4.61	26.7	19.18
8/51	1.8714	73.40	0.5842	2.85	27.0	19.24
9/51	1.2416	16.40	0.5409	2.47	27.4	19.27
10/51	0.7202	4.25	0.2013	0.59	26.3	19.11
11/51	0.2159	0.64	0.0957	0.25	24.6	19.09
12/51	0.1403	0.38	0.1746	0.50	23.2	18.65
1/52	0.0334	0.08	0.0576	0.14	22.2	18.73
2/52	0.0251	0.06	0.1401	0.38	22.9	18.92
3/52	0.1453	0.40	0.1357	0.37	22.4	19.26
4/52	0.7286	4.35	0.2497	0.78	23.4	19.30
5/52	0.2177	0.65	0.2182	0.65	23.9	18.98
6/52	0.7278	4.34	0.1310	0.35	24.6	19.25
7/52	1.6201	40.70	0.5042	2.19	25.5	19.29
8/52	1.7984	61.87	0.2257	0.68	26.2	19.29

egg production, this cannot be established as a conclusion from the present data.

Figure 2B shows that the larva count also varies seasonally with a high production in the summer and a low production in the winter months. As might be expected, there is high correlation between the log mean monthly egg and larva counts ($r = 0.818$; $P < 0.01$).

Mortality

When the eggs were counted, they were segregated into three categories—"normal," "damaged," and "agglutinated"—according to criteria established by Tester (1951: 325–326). The damaged eggs, with the inner membrane ruptured and the embryo shattered, were assumed to have suffered mechanical injury during capture. It was suggested that the agglutinated eggs, in which the yolk and embryo had disintegrated into a whitish mass, may have been dead before capture.

The numbers and percentages of eggs in the three categories, segregated according to months, are shown in Table 3. From the gross data, the (weighted) percentages of normal, damaged, and agglutinated eggs are respectively 46.2, 32.2, and 21.6. These may be compared with similar data collected in 1949 and 1950—48.4, 47.1, and 4.5—recalculated

TABLE 3
NUMBER (IN PARENTHESES) AND PERCENTAGE OF NORMAL, DAMAGED, AND AGGLUTINATED EGGS BY MONTHS

MONTH AND YEAR	NORMAL	DAMAGED	AGGLUTINATED
9/50	(129) 43.4	(49) 16.5	(119) 40.1
10/50	(102) 43.6	(66) 28.2	(66) 28.2
11/50	(32) 30.2	(29) 27.4	(45) 42.4
12/50	(71) 14.1	(138) 27.4	(295) 58.5
1/51	(29) 6.1	(242) 51.1	(203) 42.8
2/51	(66) 13.7	(222) 46.3	(192) 40.0
3/51	(4) 2.8	(109) 76.2	(30) 21.0
4/51	(124) 43.2	(143) 49.8	(20) 7.0
5/51	(784) 23.9	(1,386) 42.3	(1,110) 33.8
6/51	(1,830) 41.6	(1,555) 35.3	(1,018) 23.1
7/51	(6,110) 47.7	(4,648) 36.3	(2,048) 16.0
8/51	(3,991) 64.9	(1,089) 17.7	(1,072) 17.4
9/51	(528) 43.1	(323) 26.4	(373) 30.5
10/51	(292) 77.4	(32) 8.5	(53) 14.1
11/51	(19) 61.2	(7) 22.7	(5) 16.1
12/51	(5) 33.3	(4) 26.7	(6) 40.0
1/52	(2) 66.7	(0) 0.0	(1) 33.3
2/52	(0) 0.0	(0) 0.0	(2)100.0
3/52	(1) 5.6	(6) 27.7	(12) 66.7
4/52	(47) 24.5	(143) 74.5	(2) 1.0
5/52	(3) 6.2	(23) 48.0	(22) 45.8
6/52	(23) 12.0	(81) 42.2	(88) 45.8
7/52	(521) 37.3	(450) 32.3	(424) 30.4
8/52	(1,344) 64.7	(446) 21.5	(286) 13.8
All	(16,057) 46.2	(11,191) 32.2	(7,492) 21.6

from data discussed by Tester (1951: 338–340). The differences between investigations in the last two categories may be due, in part at least, to a change in interpretation of borderline cases of the "damaged" and "agglutinated" condition, although an effort was made to acquaint each of the several plankton sorters with the same objective criteria. The indications are that the number of agglutinated eggs averaged higher in 1950–53 than in 1949–50, but perhaps in a smaller ratio than that shown by the data (21.6 to 4.5, or 5 to 1). In any case, it is believed that the interpretation of the differences between "damaged" and "agglutinated" was reasonably consistent within the recent investigation.

The monthly percentages listed in Table 3 vary widely, but show a tendency for normal eggs to be relatively more abundant than agglutinated eggs during the summer and for agglutinated eggs to be relatively more abundant than normal eggs during the winter. The seasonal trend is illustrated in Figure 4. Because of the varying inherent accuracies of the percentages it is difficult to establish the statistical significance of the seasonal change. However, it may be shown readily that the differences in monthly ratios of normal to total and of agglutinated to total are unlikely due to chance. For example, a test of independence applied to the ratios of agglutinated to total yielded an extremely high Chi-square (3,067 for 21 degrees of freedom) which was highly significant ($P < 0.001$).

If the eggs classed as agglutinated were actually dead at the time of sampling, it would seem that this source of natural mortality was more pronounced in the winter, the period of small spawning, than in the summer, the period of large spawning. This suggests a further investigation of (1) the assumption that agglutinated eggs were dead at the time of sampling, and if this is established, (2) the causes of mortality of the eggs.

Reference may again be made to the grand geometric means for eggs and larvae (7.01 and 0.96 per 100 cubic meters) and to the great reduction in numbers (86.3 per cent). As the eggs hatch within 24 hours whereas the larvae persist in the catches for several days, the mean count for eggs would be expected to be smaller rather than larger than that of the larvae. There are several possible explanations for the relatively small mean larva counts:

(a) The larvae may be carried away from Station 4 by a slow clockwise current drift as suggested by Tester (1951: 342) following a study of variation in length distribution of the larvae.

(b) The thin filiform larvae, particularly after yolk sac absorption, may slip through the meshes of the net.

(c) The newly hatched larvae may sink below the surface layer which was sampled. Yamashita (MS: 14) has shown that in aquaria the newly hatched nehu larvae tend to sink. Although in simultaneous tows made by Tester (1951: 335) there was no significant evidence of more larvae at a depth than at the surface, the numbers caught were too few to warrant a conclusion.

(d) The newly or recently hatched larvae may suffer a high natural mortality. It seems idle to speculate further on this or other possibilities in view of the probable action of (a), (b), and perhaps (c), as outlined above.

Perusal of Table 2 will disclose that the ratio of egg to larva number varies considerably from month to month. The most striking discrepance occurs in the months of December, January, and February, 1951–52, when the mean egg count is less, rather than greater, than the mean larva count. Although in these months the comparisons are intrinsically less reliable than in others because of the small numbers involved, nevertheless the discrepance seems due to factors other than chance. The reversal of the egg to larva ratio in the winter is contrary to what would be expected from the tendency, just discussed, for the percentage of agglutinated and presumably dead eggs to be higher in the winter than the summer: this should increase rather than decrease the winter egg to larva ratio. One possible explanation of the reversal is that in the winter of 1951–52 spawning of relatively small extent took place elsewhere than at Station 4, and that the larvae drifted into the sampling area.

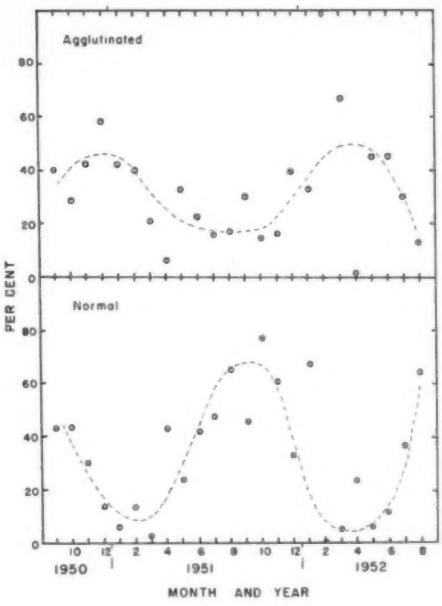

FIG. 4. Seasonal variation in the percentage of agglutinated and normal eggs.

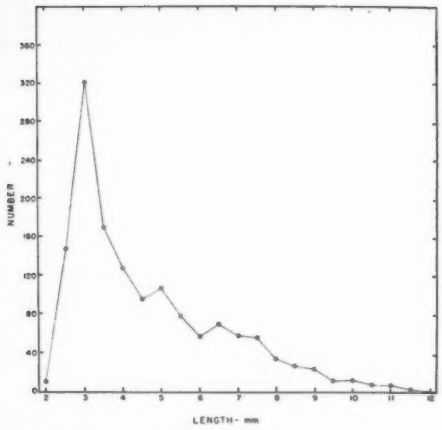

FIG. 5. Length frequency distribution of larvae.

Length Distribution of the Larvae

The nehu larvae ranged in length from about 2 to 11 mm. It is presumed that larger larvae were able to escape the net. It was hoped that the progeny of pulses of spawning could be followed by the progression of modes in the length distribution of successive samples of larvae. This was not possible because (a) the larvae were apparently dispersed from the sampling station too rapidly and (b) the samples were not taken at sufficiently close time intervals.

The composite length distribution of all larvae sampled at Station 4 is shown in Figure 5. It is similar to that shown by Tester (1951: fig. 6) in that a main mode appears at 3 mm. and less pronounced modes appear at greater lengths. The latter differ slightly in position from those reported earlier but this may be attributed to the fact that sampling was confined to one station in the present investigation and therefore did not adequately sample the larger larvae which drifted elsewhere. The minor modes are presumed to be real and to be related to the presence of "day groups." As in the previous investigation (Tester, 1951: 341), they suggest an average early growth rate of about 1.5 mm. per day.

SUMMARY AND CONCLUSIONS

1. Quantitative samples of nehu eggs and larvae were taken in replicate twice a week over a two year period at one station in Kaneohe Bay, using a half-meter plankton net. The station was located at or near a focus of abundance of eggs in the southern sector of the bay.

2. Spawning, as indicated by egg and larva catch, occurred erratically throughout the year, but with a summer maximum and a winter minimum.

3. Variation in egg production between days could not be adequately explained by variation in temperature, chlorinity, or moon phase.

4. Agglutinated eggs, with the embryo and yolk coagulated beyond recognition, formed a higher percentage than in a previous investigation. Moreover in the present material, the percentage was higher in winter than in summer. The suggestion that agglutinated eggs were dead at the time of capture should be investigated further.

5. Several possible explanations are advanced for a large decrease in numbers between the egg and larva stage, namely, drift of larvae from the sampling station, escape through the meshes of the net, sinking below the surface layers, and loss from mortality. A seasonally erratic egg to larva ratio is pointed out.

6. The sampling is not adequate to trace pulses of spawning from the egg to the larva stages. A length frequency distribution of the larvae is included showing the presence of one major and several minor modes similar to those found in a previous investigation.

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Annotated List of Birds Observed on Christmas Island, October to December 1953

JOSEPH E. KING[1]

IN OCTOBER 1953, the Pacific Oceanic Fishery Investigations of the U. S. Fish and Wildlife Service landed a small field party (the author and Mr. Richard Shomura) on Christmas Island for the purpose of installing weather instruments and sea thermographs, and to conduct a tuna bait-fish survey of the lagoon. We were on the island from October 23 to December 9, 1953, and although our time was generally occupied with the duties mentioned above, we had many opportunities to observe the interesting bird life of the island. As Christmas and other islands of the Line Island group (Fanning, Washington, and Palmyra) are rarely visited by ornithologists, we thought it worthwhile to report our observations.

The author is indebted to Dr. Frank Richardson for his helpful review of the manuscript.

Christmas Island (Fig. 1), lies in the equatorial Pacific about 1,200 miles south of Hawaii at 2° N. latitude, 157° W. longitude. It is about 35 miles in length, in a northwest–southeast direction, and about 17 miles in width. The island is a large coral atoll with a perimeter of about 105 miles. Enclosed within the outer coast is an area estimated at 382 square miles, of which approximately 250 are land and 107 are lagoon; about 25 square miles are occupied by numerous salt lakes (Wentworth, 1931). The island is generally low, averaging about 10 feet or less in elevation, except along the southern shore of the Bay of Wrecks where there are scattered sand dunes which may reach 40 feet in height.

The rainfall is quite variable but averages 25 to 35 inches a year (Bryan, 1942). Fragmentary records show an annual range from 10 inches to as much as 100 inches. The air temperature varies from a minimum of 68° or 70° F. to a maximum of 106° F. (Wentworth, 1931).

Christophersen (1927) records 24 species of vascular plants as growing naturally on Christmas Island. These include *Tournefortia argentea* trees, clumps of *Scaevola frutescens* and other low shrubs, grasses, and herbs. Although all the coconut palms now seen on the island have been planted, there were a few palm trees present at the time of Captain Cook's visit in 1777. There are now extensive coconut groves in the northwestern, northern, southwestern, and southern parts of the island.

The vertebrate fauna of the island consists mainly of the fishes that abound in the lagoon and coastal waters and the abundant bird life that forms the subject of this report. In addition there are lizards, rats, and cats; many of the latter roam in a wild state, and while they may help keep down the rat population, they also without doubt prey on the ground-nesting birds.

Great Britain claims sovereignty over the island and has brought in natives from the Gilbert and Ellice Colony to provide a labor

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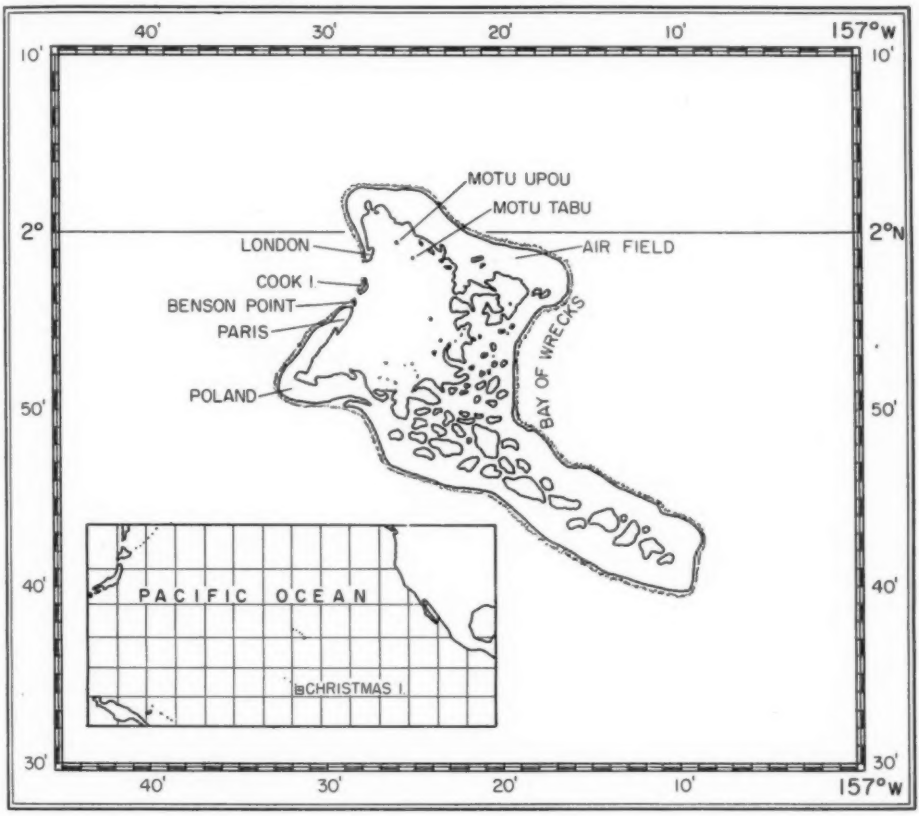

FIG. 1. Christmas Island, showing locations referred to in the text and the island's general position in the central Pacific (inset). (Drawn with modifications from USN Hydrographic Office Chart No. 1839.)

force for the plantation. There is no indigenous population.

A review of the literature describing the avifauna of Christmas Island begins with the account of its discoverer, Captain James Cook. On the afternoon of December 24, 1777, Captain Cook brought his ships the "Resolution" and the "Discovery" to anchor off the west shore of the island. On the next day—Christmas Day—he and his men went ashore at Cook Island (Fig. 1), a small patch of coral and sand separated from the main island. He states (Cook, 1784), "As we kept our Christmas here, I call this discovery Christmas Island." The vessels stayed at anchor several days to permit the men to refresh themselves and to observe an eclipse of the sun. Cook reports that there were no traces of human beings having been there before and that the number of coconut trees did not exceed 30. He had the following to say about the animal life *ibid.*, p. 188–189):

> Under the low trees above-mentioned, sat infinite numbers of a new species of tern, or egg-bird. These are black above, and white below, and with a white arch in the forehead [apparently sooty terns]; and are rather larger than the common noddy. Most of them had lately hatched their young, which lay under old ones, upon the bare ground. The rest had eggs; of which they only lay one, larger than that of a pigeon,

bluish and speckled with black. There was also a good many common boobies; a sort that are almost like a gannet [most likely the blue-faced booby]; and a sooty or chocolate-coloured one, with a white belly [the brown booby]. To this list we must add men-of-war birds; tropic-birds; curlews; sand-pipers; a small land-bird like a hedge sparrow [the kokikokiko, as named by the Gilbertese]; land crabs; small lizards; and rats.

The whaling ship "Tuscan" stopped at Christmas Island in May, 1835. Bennett (1840) gives an interesting account of the visit and states that, "Here and there among the low thicket scrubs are vast rookeries of aquatic birds, whose clamour is deafening." He mentions "sooty terns," "red-tailed tropic birds," "pure snow white petrels," probably white terns, "boobies," blue-faced boobies from the description, other "terns," probably noddies, "frigate birds," "petrels," "curlews," bristle-thighed curlews, "quail," probably golden plover, and a "sparrow-like land bird," the kokikokiko.

Streets (1877) visited Christmas Island in the vessel "Portsmouth" during the course of the United States North Pacific Surveying Expedition of 1873–75. Nine species of birds were reported and a collection was made. Father Emmanuel Rougier (1914), who at one time held a lease on the island, has published one of the most complete descriptions of Christmas Island, including its flora and fauna. He lists the following birds: frigate bird, sooty tern, grey-backed tern, Necker Island tern, Hawaiian tern, noddy tern, white tern, Christmas Island shearwater, red-tailed tropic bird, blue-faced booby, red-footed booby, and the kokikokiko (a small land bird), a total of 12 species. Kirby (1925) reports 11 species of sea and shore birds (including the bristle-thighed curlew, wandering tattler, and golden plover) plus several kinds of migratory ducks (which he does not name) as occurring on the island. He states that birds have been greatly reduced in number (prior to 1925) throughout the Line Islands as a result of land clearing and other disturbances by man. In 1921 the Whitney Expedition of the American Museum of Natural History carried on an investigation of the birds of Christmas Island. Specimens of the kokikokiko, *Conopoderas aequinoctialis aequinoctialis* (Latham), collected at this time have been described by Murphy and Mathews (1929).

The following is a list, with a few life-history notes, of the birds seen by the author during his stay on Christmas Island from October 23 to December 9, 1953. In general, Peters (1931, 1934) has been followed in respect to scientific names.

Puffinus nativitatus Streets, Christmas Shearwater. Abundant. Observed nesting with eggs and young on the islets of Motu Tabu and Motu Upou within the lagoon. Nests were in shallow tunnels or depressions overhung with grass or low shrubs.

Pterodroma alba (Gmelin), Phoenix Petrel. Abundant. Observed nesting with eggs (Fig. 2*d*) and young on the islets of Motu Tabu and Motu Upou. This petrel could be seen throughout the day, flying low over the land and lagoon, and was more commonly seen over land than was the Christmas shearwater. Nesting habits were the same as for that species.

Nesofregetta albigularis (Finsch), White-throated Storm Petrel. Uncommon. Observed near shore (October 22) when we were approaching the island from the north, and seen on several occasions flying over the lagoon and outer beach. One bird of this species was found nesting, with one egg, on the islet of Motu Tabu. The egg was in a shallow depression over-hung by a thick cover of grass.

Phaethon rubricauda melanorhynchos Gmelin, Red-tailed Tropic Bird. Abundant. Observed nesting with eggs and young (Fig. 2*c*) throughout the island. Egg usually was placed under the low shrubs of *Scaevola* or the larger *Tournefortia*.

Sula sula rubripes Gould, Red-footed Booby. Abundant and generally distributed throughout the island. Nests with eggs and young (Fig. 2*e*) were observed principally in *Tournefortia* trees.

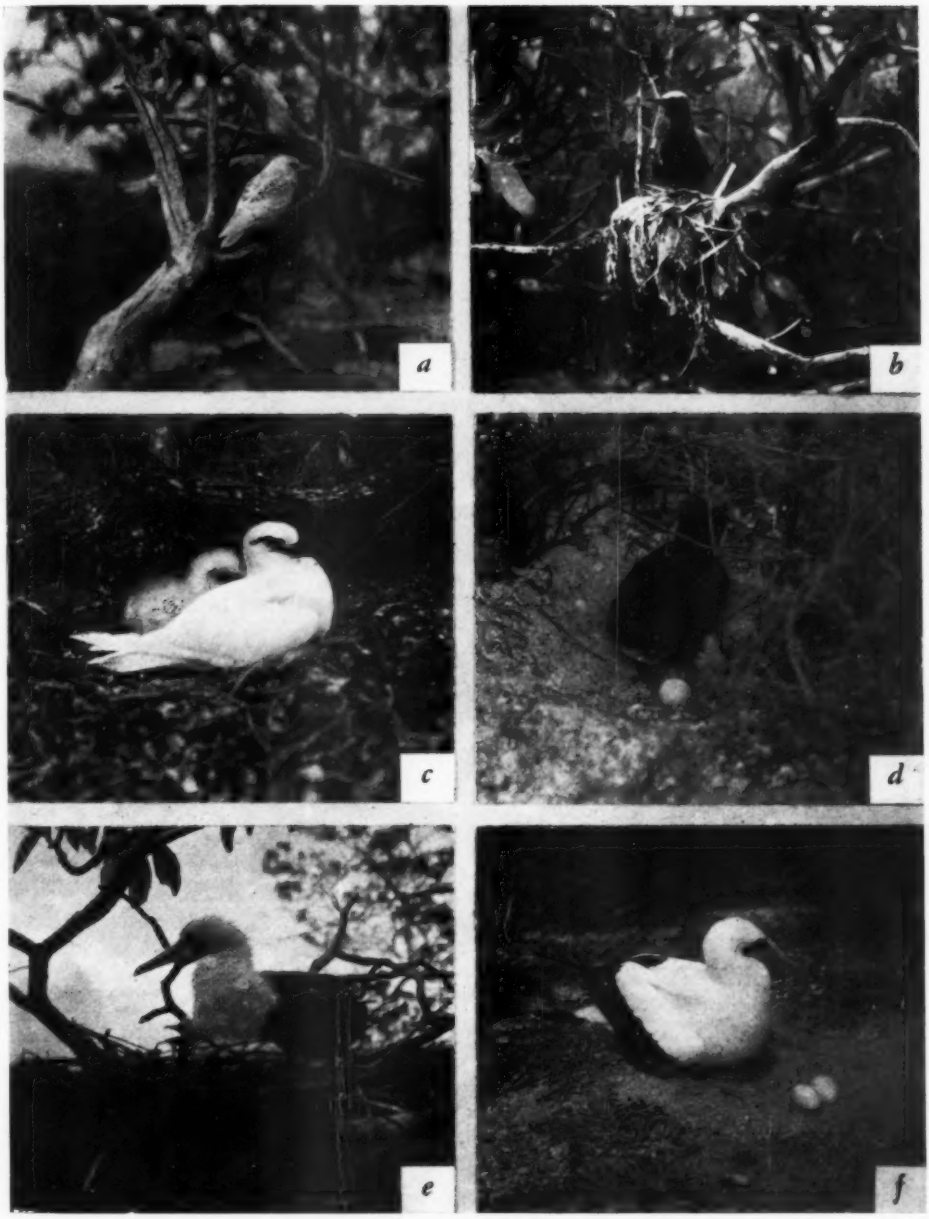

FIG. 2. Some of the birds of Christmas Island; photographed by the author. *a*, Young white tern on the remains of a nest of the white-capped noddy; *b*, young white-capped noddy on the nest; *c*, red-tailed tropic bird with young; *d*, Phoenix petrel with egg; *e*, red-footed booby with young; *f*, blue-faced booby with eggs.

Sula dactylatra personata Gould, Blue-faced Booby. Common but considerably less so than *S. s. rubripes*. Eggs and young were observed principally in the less visited areas. The eggs are deposited on the ground in a slight depression with no nesting materials (Fig. 2*f*). A booby of this species was seen setting on two eggs on October 28, one of which hatched on December 8 indicating that the incubation period exceeds 42 days.

Sula leucogaster plotus Forster, Brown Boody. Common in certain areas, such as the Bay of Wrecks and Benson Point. No eggs or young were seen.

Fregata minor palmerstoni Gmelin, Frigate Bird. Abundant, but not observed to be nesting. These birds seemed to make their living primarily at the expense of the boobies, which they would attack by diving from a considerable height and continually torment until the unfortunate booby surrendered its food. Specimens in immature plumage were common.

Sterna fuscata oahuensis Bloxham, Sooty Tern. The most abundant bird on the island. Was present in large numbers in October but appeared in huge congregations in the latter part of November and started to nest in the first week of December. The main nesting areas were located in the northwestern part of the island, between Poland and Paris, on Cook Island, and on parts of the large southeastern peninsula.

Thalasseus bergii cristatus Stephens, Crested Tern. Common; not observed to be nesting. This is the largest tern of the Pacific and not previously reported for Christmas Island.

Anous stolidus pileatus (Scopoli), Common Noddy. Common but found with eggs only on Cook Island during our visit. Eggs were deposited on the ground under *Scaevola* shrubs.

Procelsterna cerulea cerulea (F. D. Bennett), Blue-grey Noddy. Abundant. Observed with eggs and young on Cook Island and Motu Tabu. The eggs were found in areas almost barren of vegetation.

Anous minutus minutus Boie, White-capped Noddy. Common. Was nesting with eggs and young on Cook Island, Motu Tabu and Motu Upou (Fig. 2*b*). The nest was constructed of leaves, twigs, and grass and placed in the *Tournefortia* trees.

Gygis alba candida (Gmelin), White Tern. Abundant. Observed with eggs and young (Fig. 2*a*) on Cook Island, Motu Tabu, and Motu Upou. The egg is deposited on a bare horizontal trunk or limb of the larger shrubs or trees. The eggs are easily dislodged and the writer returned many eggs, which had fallen to the ground, to their former location after flushing the incubating adult bird. These terns were observed returning to their young with what appeared to be four to six small fish lined up in their beaks. This feat has been noted many times and while it is thought that the tongue may assist in the operation, the details of the phenomenon still remain a mystery.

Anas acuta tzitzihoa Vieillot, Pintail Duck. One or two ducks of this species were occasionally sighted in the ponds near the airfield. From the shore of the Bay of Wrecks, on November 18, a flock of about 20 birds thought to be pintails, were seen flying in off the ocean from the northeast.

Pluvialis dominica fulva (Gmelin), Pacific Golden Plover. Abundant. Occurring generally throughout the island even in the streets of the native village. In fact it seemed more abundant in the dry areas with little vegetation than along the beaches and mud flats. During the period of our visit birds were seen in a variety of plumage patterns from the dark-breasted breeding plumage to the light-breasted winter condition.

Numenius tahitiensis (Gmelin), Bristle-thighed Curlew. Common to abundant. Observed in many different habitats on the island, from the dry interior areas to the ocean and lagoon beaches.

Heteroscelus incanus (Gmelin), Wandering Tattler. Probably the most abundant shore

bird on the island, occurring almost everywhere near water.

Arenaria interpres interpres (Linnaeus), Turnstone. Small flocks of these birds were seen on three occasions at the ponds near the airport.

Crocethia alba Pallos, Sanderling. One bird of this species was seen near London Village on the morning of November 7.

Larus delawarensis Ord, Ring-billed Gull. An immature specimen of this species was sighted in the lagoon behind London Village on November 15. It was examined at close range twice that day and again the next two days, but not seen thereafter. This bird is certainly a rare visitor to the central Pacific and the author is not aware of any previous record of the species for the Line Island group.

Conopoderas aequinoctialis aequinoctialis (Latham), Kokikokiko. Common in the higher and more dense growths of *Tournefortia*. Old nests were found but none containing eggs or young. This species is flycatcher-like in appearance and is the only native land bird on the island. These birds stayed close to cover and were rarely seen in flight.

Although the author was in the field every day during the 7-week stay and covered the island rather thoroughly several times, except for the long peninsula extending to the southeast, it is very probable that the above list is not complete for the period of our visit. For example, the wedge-tailed shearwater (*Puffinus pacificus chlororhynchus* Lesson), one of the most abundant of the Procellariidae in the mid-Pacific, is reported to nest on the island (Alexander, 1928; Murphy, 1951) but was not seen there during our visit. The gray-back tern (*Sterna lunata* Peale) is supposed to occur throughout Oceania (Alexander, 1928) and has been observed on Christmas Island (Rougier, 1914). We believe we sighted this bird on a few occasions but were not able to identify it with certainty. The white-tailed tropic bird (*Phaethon lepturus dorotheae* Mathews) has been observed by the author on Fanning and Washington islands but not on Christmas, and according to Kirby (1925) it does not occur there. The author has also admired the brightly colored parakeets, *Vini kuhlii* (Vigors), on Fanning and Washington islands but did not find them on Christmas and probably they have never become established there (Tristram, 1883). The black-footed albatross (*Diomedea nigripes* Audubon) is common in the temperate and subtropical North Pacific and has been observed by the author as far south as 7° N. latitude (on December 14, 1953). It may occasionally visit the Line Islands area, but as yet we have not encountered it there on any of the several POFI cruises from 1950 to 1954.

Except for the golden plover, tattler, and curlew, there was a general lack of shore birds on the island during the period of our stay. Ducks also were scarce. About the middle of November, Mr. Phil Palmer of Fanning Island, which is about 150 miles northwest of Christmas, reported that a large number of ducks had just arrived on that island during a rainstorm. Apparently none of these birds reached Christmas.

Some information of interest and value was obtained from Latia, the "old man" of the island. He reported that on Christmas Island the sooty terns have two nesting periods: a mid-winter period from December to March, and a mid-summer period from June to August. About equal numbers of birds take part in each nesting. The red-tailed tropic birds nest from June to January and the frigate birds from December to June. There are some shearwaters and petrels nesting throughout the year. The boobies have eggs and young over a good part of the year, particularly during the fall and winter months. Usually a few ducks show up each winter but never in great numbers. Mr. Richard Cooper, British Officer for the Line Islands, reported that the small land bird, called the "kokikokiko" by the Gilbertese, lays its eggs in the summer months.

In summary, 22 species of birds were iden-

tified on Christmas Island during the period October 23–December 9, 1953. Of this number, 11 species were observed with eggs or with eggs and young. The author believes this to be the first report of the occurrence of the crested tern and the ring-billed gull on Christmas Island or for the Line Island area.

ADDENDUM

Since the submission of this manuscript the author has made another visit to Christmas Island, June 5 and 6, 1954. Other duties prevented a thorough survey of the Island, but through the courtesy of British District Officer Percival Roberts, a short trip was made to the islet of Motu Tabu. Species observed nesting with eggs and young were the Christmas shearwater, white-capped noddy, common noddy, white tern, and red-tailed tropic bird. The Phoenix petrel was brooding eggs, but no young were seen. The blue-grey noddy was quite abundant on the islet, but no eggs or young could be found. Sooty terns, crested terns, frigate birds, and red-footed boobies were observed flying over the lagoon. Some of the Gilbertese plantation staff informed us that the sooty terns had not yet started to nest but had already begun to congregate on the main island for their summer nesting season.

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Titaniferous–Ferruginous Laterite of Meyer Lake, Molokai, Hawaii[1]

G. Donald Sherman, Judith Fujioka, and Giichi Fujimoto[2]

The soils belonging to the ferruginous humic latosol group in the Hawaiian Islands have accumulated titanium oxide in or near the surface horizon of the soil profile. Cline *et al.* (in press) have separated this group of soils on this basis in their classification of Hawaiian soils. Sherman (1949, 1952) has shown that these soils have progressively accumulated iron and titanium oxide with soil weathering age. A highly weathered soil, rich in titanium oxide, would represent the anatase-leucoxene stage of the weathering sequences described by Jackson *et al.* (1948). This weathering stage would include anatase and leucoxene, which are hydrated amorphous titanium oxides according to Carroll and Woof (1951), both products of the weathering synthesis mechanism and ilmenite, brookite, and rutile of the weathering residue mechanism, Jackson and Sherman (1953).

During 1952 and 1953 the guava and other shrubs were cleared from a large area of land around Meyer Lake on the island of Molokai for the purpose of pasture improvement. The entire area was plowed, exposing areas of soils of extremely high titanium content. Many of these titanium-rich areas occurred as indurate dehydrated areas which are easily detected by their grayish purple color as compared to the reddish brown color of the surrounding area. A closer examination of these indurate areas revealed that they contained numerous, magnetic ferruginous concretions. The development of these concretions indicated a movement of iron in solution from the surrounding area and its redeposition from either near-surface percolating water or ascending water from the subsoil. The occurrence of the indurate areas cannot be attributed entirely to a difference in degree of slope, but rather to areas where exposure of sufficient magnitude has occurred to cause the dehydration of the hydrated oxides. The concretionary indurate soil horizons usually occurred on a gentle slope with a majority of them occurring near the foot of the slope. The accumulation of concretions appeared to be the result of micro relief in the slope or retardation of percolating waters due to reduced porosity of the soil.

It was also observed that some movement of soil aggregates and concretions did occur as the result of erosion. These could be found at the foot of the steep slope directly west of Meyer Lake. The deposits of these materials were quite distinct from the concretionary indurate layers. The latter is due to synthesis mechanism, whereas the deposits near Meyer Lake are mechanically sorted materials having different physical characteristics. They are recent deposition resulting from the removal of cover and subsequent rains.

The exposure of the area around Meyer Lake has given an excellent opportunity to

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study the condition which led to the accumulation of iron and titanium oxides in these dehydrated areas. It also offers an excellent site for the study of the movements of these oxides, and the nature of the minerals in which the oxides become stable constituents of the concretions and surface soil.

EXPERIMENTAL PROCEDURES

The soil samples were selected to give the following information: (a) The chemical composition of a typical titaniferous-ferruginous laterite profile which occurs in the indurate areas near Meyer Lake; (b) The extent of the movement of iron and titanium in solution and the nature of their deposition products by collecting samples; (c) The chemical composition of ferruginous aggregates and concretions deposited along the shore of Meyer Lake by erosion.

The representative profile was selected in a road cut on the slope above Meyer Lake. The soil belongs to the Naiwa family of the ferruginous humic latosol group. The description of this profile is as follows:

A Horizon—0 to 12 inches. Grayish purple, concretionary, slaglike, massive, indurate layer having a high bulk density. The concretions vary in size from that of a common pinhead to half an inch in diameter. Both soil and concretions are strongly magnetic. It is obvious that this horizon has accumulated iron and titanium oxides of high specific gravity.

B Horizon—12 to 20 inches. A reddish brown, friable, non-plastic silty clay loam.

C Horizon—20 to 34 inches. Rotten, fine grain, grayish lava rocks mixed with reddish brown silty clay soil. The rock was in various stages of weathering and would crumble easily by pressing in one's hand.

D Horizon—below 34 inches. Bluish gray clay which had a greasy consistency when wet.

Samples from this profile were analyzed by procedures described by Piper (1944).

A series of samples was collected in a line across an indurate area as shown in Figure 1. The indurate layer is identified readily by the grayish purple color and the hydrated soil by its reddish brown color. Two of the soil sampling sites, A and B, at the top of the slope, and one site, H, were from hydrated soil and five sampling sites were from the dehydrated indurate area. The five samples from the dehydrated area were separated into concretions and soil by screening. The analysis for oxides, as described by Piper (1944), was used to determine the chemical composition of these soils. The analysis for ilmenite, iron titanate, was made by an adaptation of a procedure described by Thompson (1952). The ferrous iron was determined volumetrically by titration with a standard potassium dichromate solution using barium diphenylamine sulphonate as an indicator after digestion of sample in HF–H_2SO_4 and dilution with a mixture of boric, phosphoric, and sulfuric acids. Ferric iron was determined by dissolving the $KHSO_4$ fusion cake with a 10 per cent H_2SO_4 solution, treatment with $SnCl_2$ and an excess $HgCl_2$, and titrated with standard potassium dichromate.

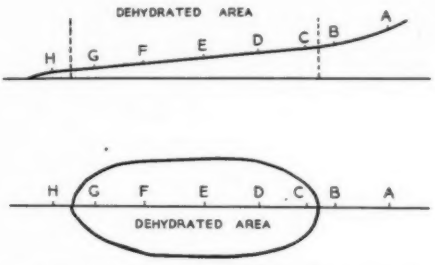

Fig. 1. Vertical and horizontal sketches of sampling sites on line across a dehydrated area near Meyer Lake.

Samples collected from the erosional deposits along the shore of Meyer Lake were analyzed in the same manner.

EXPERIMENTAL RESULTS

The chemical composition of the typical soil profile of the Naiwa family of the ferruginous humic latosol is given in Table 1.

TABLE 1
THE CHEMICAL COMPOSITION OF A TITANIFEROUS-FERRUGINOUS LATERITE LOCATED ON SLOPE TO MEYER LAKE, MOLOKAI

DESCRIPTION	DEPTH INCHES	SiO_2 PER CENT	Al_2O_3 PER CENT	Fe_2O_3 PER CENT	TiO_2 PER CENT	MnO PER CENT
Surface—grayish purple indurate layer rich in ferruginous concretions	0–12	8.78	12.16	45.98	19.22	0.19
Friable reddish brown silty clay	12–20	12.03	16.70	41.64	19.56	0.17
Rotten gray lava rock—weathered	20–34	24.80	47.10	6.60	9.20	0.22
Bluish gray silty clay	34+	17.69	46.16	12.84	2.03	0.07

The analysis of this profile shows that the chemical composition is similar to that of the soils of other profiles of the Naiwa family as reported by Sherman *et al.* (1949) and Sherman (1949, 1952). The iron oxide and titanium oxide contents were found to be high in the soil solum, being 46 and 42 per cent for iron oxide and 19 and 20 per cent for titanium oxide. The low silica content and the absence of alumino-silicate minerals, montmorin and kaolin, indicate the degree of the intensity of chemical weathering. Desilication has progressed to the point where these minerals have decomposed. The chemical composition of the rotten lava is similar to that found in other locations. Differential thermal analysis identified kaolin as the dominant mineral in the weathered material adjacent to the rotten rock.

The data presented in Table 2 show the chemical composition of the samples taken across the indurate area, Figure 1. The titanium oxide content of the samples ranged from 10.2 to 20.6 per cent with the highest levels occurring within the dehydrated indurate area. The titanium oxide content of the concretions was approximately one-half of that found in the soil of the same sampling site. The concretions retained on a 40-mesh screen amounted to 30 to 43 per cent of the weight of the soil. The iron oxide content of the soil ranged from 33.1 to 57.4 per cent in the indurate area as compared to 21.4 to 37.6 per cent in the hydrated reddish brown soils. The iron oxide content of the concretions was very high, ranging from 65.7 to 74.6 per cent. Aluminum oxide content of the soil and the concretions from the indurate area was very low. The silica content of the concretions was extremely low with 4.1 per cent being the greatest percentage found.

The ferrous and ferric iron contents of the soil were determined in order to estimate the percentage of ilmenite present in the soil. The iron occurring in ilmenite ($FeO \cdot TiO_2$) is in the ferrous form. One can assume that the ferrous iron in the soil may exist in the mineral ilmenite provided weathering has progressed under conditions of excellent oxidation and drainage. However, it is known that ferrous iron can exist in other minerals common to advanced stages of weathering such as magnetite ($2\ FeO \cdot Fe_2O_3$). The results of the ferrous and ferric iron determination are given in Table 3.

The data in Table 3 show that the ferrous iron content of the concretions is much lower than that found in the soil. The ferrous iron content of the concretions was 3.3 and 4.1 per cent; in the soil it ranged from 12.0 to 14.8 per cent. When the ilmenite content is calculated from the ferrous iron content, there is an excess of free titanium oxide in the concretion. Some free titanium oxide does

TABLE 2

THE CHEMICAL COMPOSITION OF SERIES OF SAMPLES TAKEN AT INTERVALS ALONG A LINE CROSSING A DEHYDRATED TITANIFEROUS–FERRUGINOUS LATERITE AREA ON A SLOPE OF A HILL NEAR MEYER LAKE, MOLOKAI

PROFILE SITE ON SLOPE	DESCRIPTION	DEPTH INCHES	SiO_2 PER CENT	Al_2O_3 PER CENT	Fe_2O_3 PER CENT	TiO_2 PER CENT	MnO PER CENT
A	Reddish brown granular material having a high bulk density	0–9	20.72	13.00	21.40	14.80	0.02
A	Reddish brown friable silty clay containing some gray aggregates	9–18	16.50	22.00	18.44	10.78	0.07
B	Grayish brown granular material having high bulk density	0–10	17.61	9.90	39.40	19.60	0.08
B	Dark reddish brown clay having plastic gray nodules	10–25	10.31	11.00	46.60	10.40	0.07
C	Grayish purple soil material	0–25	17.73	9.70	53.20	17.00	0.34
C	Grayish purple concretions from slaglike material	0–25	4.13	9.10	70.90	11.20	0.13
D	Grayish purple soil material	0–24	17.32	1.42	57.44	20.56	0.15
D	Grayish purple concretions from slaglike material	0–24	2.60	6.10	72.82	11.18	0.08
E	Grayish purple soil material	0–30	17.21	8.70	46.40	18.90	0.20
E	Grayish purple concretions	0–30	3.89	12.00	65.70	11.40	0.14
F	Grayish purple soil	0–9	17.80	6.50	46.40	18.50	0.56
F	Grayish purple crystalline concretions	0–9	2.41	8.30	71.50	13.40	0.11
F_1	Grayish purple soil	9–30	20.20	6.20	47.66	19.40	0.30
F_1	Grayish purple crystalline concretions	9–30	3.60	3.30	74.60	12.40	0.13
G	Grayish purple slaglike surface soil	0–9	11.02	19.00	33.10	15.40	0.09
H	Reddish brown granular surface soil	0–20	12.38	16.00	37.60	10.20	0.10

TABLE 3

THE ANALYSIS OF SAMPLES OF SOIL FROM THE NAIWA SOIL FAMILY AREA OF MEYER LAKE, MOLOKAI, FOR TYPES OF IRON OXIDES IN ORDER TO CALCULATE THE POSSIBLE HYPOTHETICAL PERCENTAGE OF ILMENITE FROM THE FERROUS IRON AND TITANIUM OXIDE CONTENT

SAMPLING SITE	DEPTH INCHES	TOTAL Fe PER CENT	Fe_2O_3 PER CENT	FeO PER CENT	TiO_2 PER CENT	CALCULATED ILMENITE CONTENT	
						From TiO_2 PER CENT	From FeO PER CENT
A	0–9	25.3	20.8	14.8	13.7	26.0	31.2
A	9–18	22.1	15.8	12.6	4.3	8.2	26.6
B	0–10	31.7	29.3	12.2	17.3	32.8	25.8
B	10–25	34.6	32.5	13.1	6.0	11.5	27.8
D—soil	0–24	46.4	53.0	12.5	22.7	43.1	26.3
D—concretions	0–24	50.4	68.4	4.1	9.8	18.6	8.6
F—soil	0–9	32.3	30.8	13.7	19.7	37.4	28.9
F—concretions	0–9	50.2	68.4	3.3	10.9	20.6	7.0
G	0–9	39.4	48.6	7.0	18.9	35.8	14.7
H	0–20	34.6	36.6	12.0	14.7	28.0	25.3

occur in all of the samples. A much higher percentage of free titanium oxide occurs in the concretions. The data support the hypothesis that the primary titanium minerals break down in weathering to form a soluble form of titanium which is deposited and accumulated in concretions by weathering synthesis mechanism. Analysis by X-ray diffraction of similar soils has identified anatase, a secondary titanium oxide mineral. Further evidence of the occurrence of free titanium oxide and the weatherability of the primary titanium minerals can be obtained from the analysis of these samples for titanium oxide and ferrous oxide. The analysis of the surface soil of site A showed that this soil contained 13.7 per cent TiO_2. This amount of TiO_2 would require 15.1 per cent ferrous oxide to form ilmenite. The ferrous oxide content was found to be 14.8 per cent, which would mean that in this soil most of TiO_2 would exist as ilmenite with a small fraction of free titanium oxide. The results of analysis of the surface soil of the same sampling site indicate 22.7 per cent TiO_2 and 12.5 per cent ferrous oxide. The titanium content of this soil would require 25.1 per cent ferrous oxide to exist as ilmenite. The analysis of the soil shows that there is approximately 12 per cent free titanium oxide.

The data in Table 3 show a movement of iron in this deposit as shown by the high iron oxide content of the concretions. The ferric iron oxide content of the concretions was found to be 68 per cent as compared to a much lower content in the soil. The concretions have accumulated ferric oxide. The dehydrated soil has a higher content of ferric oxide than the soil of the hydrated soil area. The dehydrated soil and concretions are strongly magnetic, and as the concretions have a low ferrous oxide content the presence of maghemite is suggested. Sherman and Kanehiro (1954) reported similar observations in the analysis of concretions of the Naiwa family on Kauai.

The derived molecular ratios are given in Table 4 for some of the samples of this area. The silica to sesquioxide ratio of these samples ranged from 0.35 to 1.10 with the highest ratio occurring in the sample from the top of the slope. The silica to sesquioxide ratio of the concretions was found to be very low, 0.08 and 0.12. The silica to iron oxide (ferrous oxide + ferric oxide) ratio was found to be similar to the silica to sesquioxide ratio except that it was slightly higher. The ratio of ferrous oxide to titanium oxide was lower in the dehydrated soil area, which indicates that titanium oxide increased with dehydration.

TABLE 4
THE DERIVED MOLECULAR EQUIVALENT RATIOS FROM DATA GIVEN IN TABLES 2 AND 3 TO SHOW THE RELATIVE ACCUMULATION OF IRON AND TITANIUM OXIDES

SAMPLING SITE	DEPTH INCHES	DERIVED MOLECULAR RATIOS			
		$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{FeO}{TiO_2}$	$\frac{2\ FeO}{Fe_2O_3}$
A	0– 9	1.10	1.28	1.19	0.80
B	0–10	0.78	1.05	0.78	0.46
D—soil	0–24	0.67	0.69	0.61	0.26
D—concretions	0–24	0.12	0.13	0.46	0.07
F—soil	0–9	0.84	1.02	0.77	0.49
F—concretions	0–9	0.08	0.09	0.33	0.05
G	0–9	0.35	0.53	0.41	0.16
H	0–20	0.44	0.66	0.90	0.36

TABLE 5
CHEMICAL COMPOSITION OF SEDIMENTS FOUND ALONG THE SHORES OF MEYER LAKE, MOLOKAI

DESCRIPTION OF EROSIONAL MATERIALS	SiO_2 PER CENT	Al_2O_3 PER CENT	Fe_2O_3 PER CENT	TiO_2 PER CENT	MnO PER CENT
Silt from lake bottom	13.77	16.80	30.64	22.36	0.17
Coarse ferruginous concretions collected from shoreline of lake	8.62	9.50	46.70	20.56	0.07
Small pebbles found along shoreline	20.05	13.40	35.16	6.32	0.14

The ratio of ferrous oxide to ferric oxide was low in the soil samples, ranging from 0.16 to 0.80. This ratio was extremely low in the concretions, 0.05 and 0.07.

The data given in Table 5 were obtained from the analysis of the shoreline sediments of Meyer Lake. The silt from the lake bottom contained 22.36 per cent titanium oxide. The black crystalline minerals of titanium and iron oxides were easily identified in the water deposited silt. The coarse ferruginous concretions found at the foot of the slope, but on the shoreline where wave action could sort the material, contained 20.56 per cent titanium oxide. Other sorted soil aggregates having a lower specific gravity had a much lower titanium oxide content, 6.32 per cent. The iron oxide content of all of these materials was greater than 30 per cent. The silt material would have an appreciable amount of free titanium oxide.

SUMMARY

The titaniferous–ferruginous laterite areas in the Meyer Lake area of Molokai have been investigated to determine the nature of the weathering processes responsible for their development. The soils of this area belong to the Naiwa family of the ferruginous humic latosol group. These soils have accumulated iron and titanium oxides in the surface horizon. Indurate, concretionary, slaglike surface areas form on the slopes as a result of dehydration of the soil minerals. The concretion content of these indurate areas ranges from 30 to 43 per cent of the weight of the soil.

The soils of the indurate layer have a much higher content of titanium oxide and iron oxide than the hydrated friable soil in the adjacent areas. The highest content of iron oxide in the soil was 53 per cent and of titanium oxide, 21 per cent. The concretions were made up predominantly of iron oxide which amounted to as much as 72 per cent of the weight of the concretion. The titanium oxide content of the concretions ranges from 11 to 13 per cent. The occurrence of these oxides in concretions is conclusive evidence of their movement in soluble form, as the development of concretions can only be considered to be a product and a phase of weathering synthesis processes.

The fractionation of free titanium oxide and combined titanium was attempted through the analysis of these samples for ferrous oxide. The maximum possible content of ilmenite would be obtained when all of the ferrous oxide is assumed to occur in the mineral ilmenite. The data obtained by this analysis revealed that in the indurate soil and concretions, it was possible for appreciable quantities of titanium to exist as the free oxide. In some of the soil, at least half of the titanium existed as the free oxide, anatase.

The titanium and iron oxides accumulate in erosion sediments due to their specific gravity. There is a substantial difference between characteristics of the erosion deposits and the indurate layers.

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Alicaligus tripartitus gen. et sp. nov., a Caligid Copepod found on the Gills of *Sarda orientalis* (T. & S.) [1]

SUEO M. SHIINO[2]

THE NEW PARASITIC COPEPOD which forms the object of the present paper was found by the author on the gills of *Sarda orientalis* (T. & S.) at Owase, Mie Prefecture, Japan. It was rather small and its outward appearance was very peculiar. A closer examination revealed that it belongs to the suborder Caligoida and, according to the structure of the first and the last legs, ought to be classed within the family Caligidae. However, it cannot be referred to any of the hitherto known genera of this family, but evidently forms the type of a new genus, the diagnosis of which is given below. The parasite sticks to a host gill filament lengthwise, grasping it by the second maxillipeds and directing the tail to its free end. Unlike orginary caligids, the new one does not appear to be capable of swimming, at least in the mature stage.

ALICALIGUS gen. nov.

FEMALE. Cephalon and first 3 thoracic segments fused into a strongly convex carapace, with its lateral parts bent ventrad as paired folds. Fourth segment small, without dorsal plates. Genital segment expanded, much larger than carapace. Abdomen likewise dilated, 1-segmented. Frontal plates with sucking disks. Cephalic appendages as in *Caligus*. First maxillae and sternal furca absent, second maxillae close to sides of mouth tube. First and last pairs of legs uniramous, 3-jointed. Other legs biramous, with rami 3-jointed in second pair, but 1-jointed in third pair. Endopodites of latter rudimentary. Caudal rami laminate.

MALE. In general appearance much different from female, but resembling ordinary caligid males. Carapace flattened; neither genital segment, nor abdomen expanded. First maxillae present. Otherwise as in female.

Type species: *Alicaligus tripartitus* n. sp.

Alicaligus tripartitus sp. nov.
Figs. 1, 2

5 females and 3 males. One of them, a female, has been selected as the holotype, others are paratypes. They are preserved in Mie Prefectural University.

FEMALE. Body divisible into 3 regions, connected one with another by narrowed articulation: carapace, fourth thoracic plus genital segments, and abdomen. Length 3.13 mm., carapace 0.83 × 1.00 mm., fourth plus genital segments 1.08 × 1.68 mm., abdomen 1.30 × 1.52 mm., and egg strings 1.62 × 0.33 mm. Opaque, whitish, without pigment.

Carapace quadrilateral in dorsal view, strongly convex above, with lateral parts curved ventrad as a pair of oblong folds. Front somewhat prominent medially, eyes close to anterior end. Dorsal surface uneven, more or less rugose, hardly divisible into dis-

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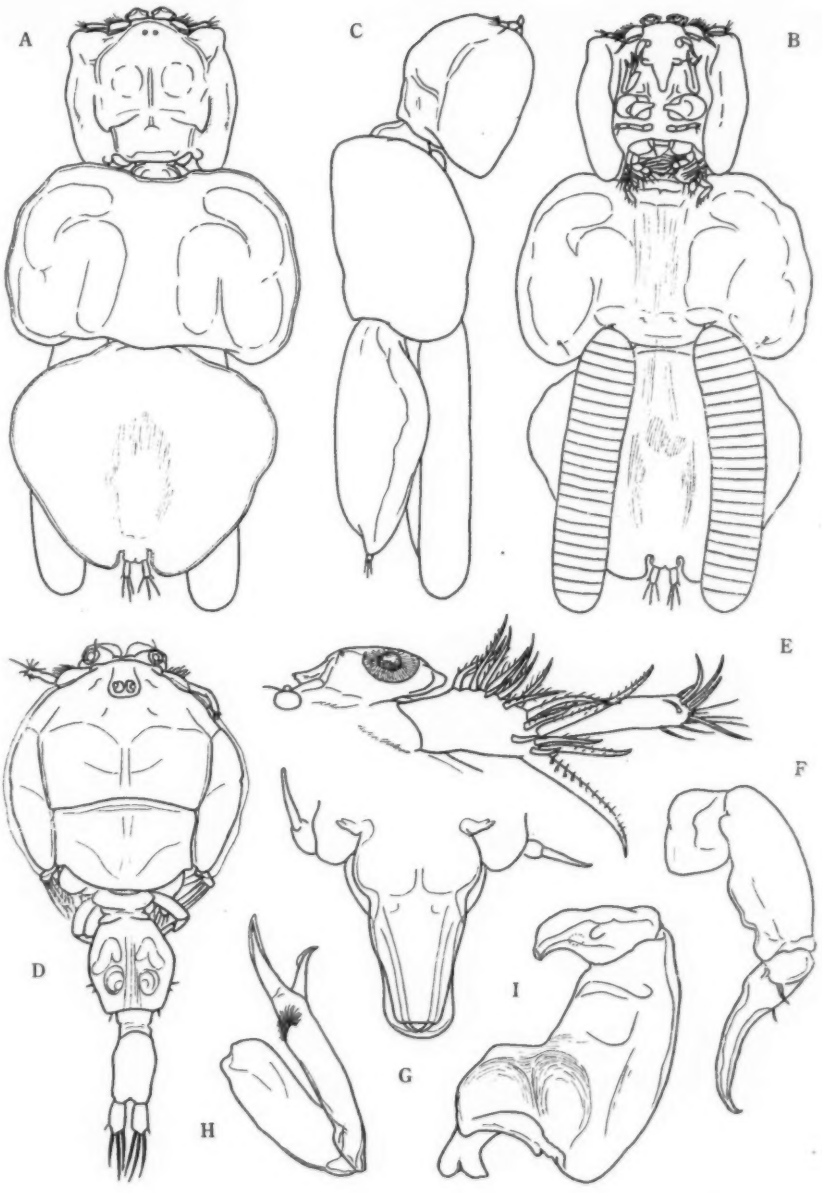

FIG. 1. *Alicaligus tripartitus* n. sp. A–C, dorsal, ventral, and lateral aspects of female; D, dorsal aspect of male; E–I, female; E, first antenna with sucking disk, ventral aspect; F, second antenna; G, mouth tube and second maxillae; H, first maxilliped; I, second maxilliped. A–C ×27, D ×47, E, G, H ×170, F ×340, I ×120.

TABLE 1
ARMATURE OF THE LEGS OF *Alicaligus tripartitus* N. SP.

LEGS	BORDERS	STERNAL PLATE	PROTOPODITE		EXOPODITE			ENDOPODITE		
			I	II	I	II	III	I	II	III
I.....	outer inner		1p 1p		1h c	4H c				
II.....	outer inner	f	1P, 1rh	f, 1h f, 1rh	f, 1H c, 1P	1H c, 1P	1rh, 1h, 1Q 5P	C 1P	C c, 2P	6P
III.....	outer inner	f	C, 1h 1P, f, 1rh, CC		1H′, 2CC 1p, 2H			C 1P		
IV.....	outer inner		1p		1H	3H				

Abbreviations in the table: C, row of cirri; CC, area covered with cirri; c, row of hairs; f, membraneous flange; H, longer spine; h, shorter spine; H′, hook; P, longer plumose spine; p, shorter plumose spine; Q, spine ciliated on one side, rimmed with membrane on the other; rh, rudimentary spine. Roman numerals indicate the numerical orders of legs, or of joints composing them, and Arabic the numbers of spines or other structure with which they are armed.

tinct areas; grooves bordering areas largely obliterated leaving a pair of L-shaped wrinkles on posterior region. Fourth thoracic segment small, 0.3 as wide as carapace, one-third as long as wide, and narrowed anteriorly. Genital segment longer than carapace, more than a half wider than its own length; lateral parts expanded as a pair of wings, slightly bent ventrally, with well-rounded margins. Anterior margin with shallow median depression to receive the preceding segment, posterior margin with insignificant obtuse lobe on either side. Abdomen expanded as a flattened, cordiform region which is only slightly narrower than genital one, but longer, and wider anteriorly than posteriorly. Its anterior end abruptly narrowed for articulation with genital segment, posterior end produced as pair of blunt lobes with shorter, narrower, quadrate, median lobe between them.

Frontal plates a pair of small, transversely fusiform lobes, separated by a median sinus; each lobe with an oval sucking disk on ventral face, not covering first antenna. First antennae with apical joint rodshaped, tipped by stiff setae, basal joint more slender than usual, but fringed with relatively longer plumose spines. Terminal joint of second antennae with sharp, slightly curved tip and 2 basal spinules, preceding joint about as long as terminal, but broader, with rugged posterior border, basal joint very short. Mouth tube broad, conical. First maxillae absent. Second maxillae close to side of base of mouth tube, with swollen base and fusiform apex. First maxillipeds end in 2 unequal, sharp, winged claws and with transverse row of setae a little before base of claws. Palm of second maxillipeds with strong basal bulge on inner side, claw with 2 papillae, one on each side of broad base. (Terminal part of the claw was unfortunately damaged when the body was detached from the host gill in all specimens.) Sternal furca wanting. All pairs of legs small and feeble. Setae fringing spines of legs rather sparser than in ordinary caligids. Armature of each pair of legs as indicated in Table 1.

First legs devoid of any spines on inner border of third joint; terminal spines unequal in length, with or without fringing hairs. Rudiment of endopodite in the form of relatively large, conical lobe. External spine on first two exopodite joints of second legs well-developed and pectinate on two opposite sides;

FIG. 2. *Alicaligus tripartitus* n. sp. A–H, female; I–O, male. A, first swimming leg; B, second leg; C, third leg; D, external border of first two endopodite joints of second leg; E, rami of third leg; F, fourth leg; G, apical part of same; H, caudal ramus, ventral aspect; I, frontal plate, first and second antennae, first and second maxillae, in situ; J, second antenna; K, first maxilla; L, second maxilliped; M, apical joint of first leg; N, rami of third leg; O, posterior part of body, ventral aspect. A, D, E, G, K, M, N ×340, B, F, H, I ×170, C, J ×202, L, O ×120.

basal spine on outer border of third joint rudimentary, middle one stouter, apical one ciliated on inside, winged on outside. Exopodite of third legs obovate, with two outer, finely pectinate spines and inner plumose one; apical portion of basal hook elongate, straight, and doubly edged with fine pectination. Endopodite small lunular lobe indistinctly separated from basal apron. Ventral face of latter with short cirri covering small area close to boundary with median plate. Fourth legs 3-jointed. Apical spines graded in length from within outwards, middle one subequal to one on penultimate joint, each finely pectinate and accompanied at base by transverse row of minute spinules. Genital segment with short spine on ventral face of each posterolateral lobe. Caudal rami terminal, oblong, armed with 3 plumose spines at end, another similar, but much shorter, at inner distal angle, two at outer angle, and minute cirrus on ventral face near anterior end, also with row of hairs on inner border. Egg tubes relatively broad not extending much beyond abdominal end.

MALE. Similar to other caligid males in general appearance; 1.45 × 0.79 mm., excluding caudal rami. Transparent, colorless.

Carapace half length of body, about as long as wide, orbicular, with well-rounded sides, and slightly convex above; anterior border narrow. Dorsal ribs forming **H**, dividing carapace into narrow lateral and broad central areas. Longitudinal ribs straight, slightly divergent forward, reaching nearly to carapace margin, each united to margin by short diagonal rib. Transverse rib at posterior three-fifths of carapace, only slightly arched forward. Eyes close to anterior end of cephalic area. Thoracic area broadly rounded on free margin, which extends beyond lateral lobes. Sinuses undeveloped. Fourth thoracic segment about one-fourth as wide as carapace, half as long as wide, widest through limb bases, having acuminate sides and short, more or less rugose, posterior waist. Genital segment two-fifths as long as and two-fifths as wide as carapace, barrel-shaped, with broadly rounded sides. Abdomen slightly longer than preceding segment, but narrower, and 2-segmented; anterior segment short, somewhat wrinkled on surface and irregular on sides, posterior segment much longer, oblong, with even sides and bifurcate end.

Frontal plates small, but prominent, and separated by broad median sinus, each with broad membrane and short spinule as well as circular disk. Terminal joint of second antennae short but sharp, prehensile claw, with one spine; second joint columnar and folded over basal joint which articulates with sternum by broad base. Each first maxilla an elongate spine, with slightly curved tip. Palm of second maxillipeds with large basal bulge on anterior face; claw elongate, sharp, well-curved, with short spinule on posterior face and papilla on other face. Exopodite of third legs with short extra spine next outside innermost spine, their basal apron without spine on outer margin. Genital segment with fifth and sixth leg rudiments on ventral surface, fifth somewhat behind center of segment on either side as papilla tipped by 3 spinules, sixth represented by broad, longitudinal ridge at each posterolateral angle with single spinule remaining. Otherwise as in female.

REMARKS. *Alicaligus* appears to be more or less nearly allied to *Caligodes* Heller, *Parapetalus* Steenstrup and Lütken, and *Abasia* Wilson, all of which have the posterior body segments either expanded or elongate. It may be distinguished from the species already known in those genera by one or a combination of the following characters: the fourth segment is very small in size, the genital segment has no processes of any kind, and the abdomen is not only elongate, but also expanded. Although the new genus resembles most closely *Parapetalus hirsutus* (Bassett-Smith) in the constitution of those segments, it is much different in the mode of life and in the structure of the carapace. The present species clings to the host gills without moving

about, whereas *P. hirsutus* crawls over the inside of the gill operculum, and is, further, capable of swimming to a certain extent. The carapace in the former has the lateral parts folded over ventrally and is not flattened as in the latter. In this point, *Alicaligus* differs from *Caligodes* also, but resembles *Abasia*. The carapace of *Alicaligus*, however, is not produced forward as a narrowed neck and is furnished with sucking disks on the frontal plates. In addition the genital segment and the abdomen are relatively broader than in *Abasia*. *Alicaligus* differs, finally, from any of the known genera in that the third legs have 1-jointed rami, the inner member of which is almost rudimentary.

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Genetics of Flower Color in *Asystasia gangetica*, Linn.[1]

H. KAMEMOTO and W. B. STOREY[2]

ASYSTASIA GANGETICA, LINN., also known synonymously as *Justicia gangetica*, Linn. and *A. coromandeliana*, Nees. (Alston, 1931) is a procumbent, clambering herb of the plant family Acanthaceae. It is commonly called "zigzag plant" from its habit of growth. It is indigenous to the tropics of the Old World from Malaya to Africa.

The time of its introduction into the Hawaiian Islands is unknown. From a few scattered plants of 20 years ago, it has multiplied rapidly and become widely distributed through the island group. It flowers and sets seeds profusely under a wide range of environmental conditions, from wet to dry and from sunny to shady. It grows luxuriantly in partial shade, which has led to its adoption as an ornamental plant for growing around buildings and along fences. It is propagated vegetatively very easily by means of cuttings.

Purple appears to predominate among the flower colors of wild plants of *A. gangetica* in the Hawaiian Islands, but white and yellow are also to be seen. Plants with pale purple, white, yellow, and pink flowers are recorded in the literature (Hooker, 1885; Bailey and Bailey, 1946; Bailey, 1942; Neal, 1948). The occurrence of a number of variants in color of flower, and the ease of propagation and culture make the species a favorable subject for a genetical study of flower color.

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A. gangetica has leaves that are opposite, exstipulate, and ovate to cordate with the margins entire. The inflorescence is a terminal raceme 5–12 cm. in length, ultimately bearing 10 to 15 flowers. The flower is gamopetalous, with an inflated tube and an expanded limb. The tube is straight, and about 2.5 cm. in length. The limb comprises five lobes, and measures about 3 cm. across. There are four epipetalous stamens which are inserted in pairs on the tube about halfway between the base and the throat. The ovary is superior. It develops into a 2-celled, 4-seeded capsule about 2.5 cm. in length, which when mature dehisces with explosive force, usually around midday. The seeds are dark, thick-coated, flattened, and more or less circular in outline measuring about 4 mm. in diameter.

Excepting in those flowers which have purple coloration on the outer epidermis of the limb extending into the dorsal portion of the corolla tube, the tube is pale yellow. Even the white flower which has a white limb has a pale yellow tube. In flowers that have the inner epidermis of the corolla limb colored purple, the median lower lobe is darker than the rest of the limb.

MATERIALS AND METHODS

Several different flower color types were gathered from a number of localities in the vicinity of the city of Honolulu. These were grown in the greenhouse and used as parents. Descriptions of the flowers of the parental plants follow:

1. Yellow with inner epidermis of limb

medium purple, resulting in a bronzy color. (From Pensacola Branch Station of the Hawaii Agricultural Experiment Station.)

2 and 16. Inner epidermis of limb dark purple and outer epidermis of limb and back of tube purple. (From University Avenue roadside.)

3, 4 and 5. Entire limb yellow. (From Pensacola Branch Station.)

6, 14 and 15. Yellow with inner epidermis of limb pale purple resulting in a light bronzy color. (From Pensacola Branch Station.)

7. Inner epidermis of limb white and outer epidermis of limb and back of tube purple, resulting in light pinkish color. (From Army Port and Service Command Nursery.)

8. Inner epidermis of limb yellow and outer epidermis and back of tube purple resulting in a light bronzy color. (From Army Port and Service Command Nursery.)

9. Entire limb white. (From Army Port and Service Command Nursery.)

10 and 13. Inner epidermis of limb dark purple, and outer epidermis of limb and back of tube purple. (From Army Port and Service Command Nursery.)

11. Inner epidermis of limb dark purple and outer epidermis of limb and back of tube pale purple. (From Army Port and Service Command Nursery.)

12. Inner epidermis of limb dark purple. (From Army Port and Service Command Nursery.)

17. Entire limb white. (From University Avenue roadside.)

18. Entire limb white. (From Pensacola Branch Station.)

Culture

All plants were grown in the greenhouse. When the seeds from the first crosses were planted, they germinated sporadically. The germination period extended over several months, and it required about a year before the complete recording of the flower types could be made. This difficulty was overcome when Akamine (1947) found that the seeds undergo a period of dormancy, and that by treating them in petri dishes with alternating temperatures, dormancy may be broken, resulting in their germination within a period of two weeks. The germinated seeds were then transplanted into soil. By employing Akamine's technique, the recording of flower types was greatly facilitated, for the plants came into flowering early and at approximately the same time.

It was also found that *A. gangetica* responds to day length; that is, it makes primarily vegetative growth during the summer months while it flowers profusely during the rest of the year. It takes about six months for the plants to flower if the seeds are planted in early summer. On the other hand, during the winter months it takes only three to four months from the time of planting of seed to the first flower.

Pollination

The flower of *A. gangetica* is protandrous. On the day of anthesis the pollen is shed, usually completely by noon. However, the stigma is not receptive until the following day when the upright style bends at the stigmatic end and a sticky substance is exuded on the stigmatic surface. The period of receptivity of the stigma is two to three days. For emasculation the corolla of a newly opened flower is pulled off in the morning carrying the stamens with it and leaving the pistil exposed. Pollination is done the following morning when the pollen from a newly opened flower of a desired type is applied by touching an anther to the sticky stigmatic surface. It was necessary to cross a number of flowers to get a large population, for from one pollinated flower the maximum number of seeds obtainable is four. Actually, an aver-

age of less than three seeds per capsule was obtained.

The parental plants were selfed to see whether they were true breeding. Upon segregation of the offspring the ratios were recorded. Several crosses among the parental plants were made, and the resulting F_1 types noted. The F_1 plants were subsequently selfed or, where convenient, backcrossed to get the segregating ratios.

RESULTS AND DISCUSSION

Flavone Colors

WHITE. With the white flowers, the limb of the corolla is self-white, but the tube is pale yellow, as mentioned earlier. The whites were found to breed true for white. Also, when two whites were crossed, only whites were obtained. When these white flowers were exposed to ammonia vapor, the corolla turned yellow as it does in many other flowers (Buxton, 1932; Lawrence, 1931; Mehlquist, 1939; Scott-Moncrief, 1936). When such a reaction takes place, it is believed that an ivory anthoxanthin, probably apigenin, is present, which upon treatment with ammonia is converted into a yellow anthoxanthin, probably luteolin.

YELLOW. The yellow pigment in this species is a water soluble flavone, which turns orange when placed in ammonia vapor, similar to that found in Dahlias (Lawrence, 1931). The coloration occurs in the inner epidermal layer of the limb as well as the hypodermal layers. The yellow parent plants bred true for yellow. When yellow flowers were crossed with white flowers, all of the F_1 flowers were yellow. The subsequent F_2 generation segregated into a 3:1 ratio and the backcross to the white into a 1:1 ratio. The results are shown in Table 1.

Yellow, then, is a simple dominant to white and *Y* has been designated as the gene necessary for the production of yellow pigment. Gene *Y* when homozygous recessive results in white flowers in the absence of other flower colors.

Anthocyanin Colors

A close examination of the purple colored flowers revealed that the anthocyanin sap pigment occurs in two definite patterns, one in which the pigment is found in the inner epidermal layer of the limb and the other in which the coloration occurs in the outer epidermal layer of the limb and extends to the base of the tube. In order to make a distinction between the two patterns of coloration, the former will be designated hereafter as purple, and the latter as purpleback, due to the fact that the back of the tube is colored in addition to the outer epidermis of the limb. The anthocyanin pigment is basically purple, with its variations ranging from bluish purple to purplish red. It appears that where the background is white, bluish purple seems to exist, whereas when the background is yellow, the color tends to be reddish purple or bronze. The purple pigment also seems to be affected by the light intensity, and the age of the blossom. With aging, the color tends to turn bluish.

TABLE 1
THE RATIO OF YELLOW TO WHITE FLOWERS IN THE F_2 AND BACKCROSS PROGENIES OF *White* × *Yellow* IN *Aystasia gangetica*

PROGENY	OBSERVED		CALCULATED		CHI-SQUARE
	Yellow	White	Yellow	White	
F_2	33	9	31.5	10.5	.285
Backcross	25	26	25.5	25.5	.020

Chi-square = 3.841 at 5% level.

TABLE 2
THE RATIO OF PURPLE TO NON-PURPLE FLOWERS IN THE F_2 GENERATION OF CROSSES BETWEEN PURPLE AND NON-PURPLE IN *Asystasia gangetica*

PROGENY	OBSERVED		CALCULATED		CHI-SQUARE
	Purple	Non-Purple	Purple	Non-Purple	
(12 × White) Selfed	69	16	63.75	21.25	1.729
(11 × White) Selfed	74	27	75.75	25.25	.162
(1 × White) Selfed	9	3	9	3	.000
(6 × White) Selfed*	84	22	79.5	26.5	1.019
Total	236	68	228.0	76.0	1.123

Chi-square = 3.841 at 5% level.
* The cross 6 x *White* resulted in both purple and non-purple. The F_2 here is the result of selfing the purple form.

PURPLE. The parental plants 1, 11, 12, and 16 were determined to be homozygous for purple. Parental plant 6 was heterozygous for purple, segregating into 3 purple to 1 non-purple. When flowers homozygous for purple were crossed to white, the resulting F_1 progenies were all purple. In the F_2 generation as shown in Table 2 the combined ratios were 236 purple to 68 non-purple, a good 3:1 ratio, indicating that purple is dominant to non-purple. The symbol *P* has been assigned to the gene responsible for the production of purple color. Gene *P* when homozygous recessive will result in white flowers in the absence of other flower colors.

It was observed in the first few crosses between dark purple and non-purple forms that the flower color of the F_1 generation was slightly less intense than the purple parent and that colors of the F_2 generation segregated into light and dark forms. This suggested the possibility of additive effects of gene *P*. Upon selfing pale purple parent 6, which was heterozygous for that factor, the offspring segregated into 3 purple to 1 non-purple, and among the purple progeny, both pale and dark forms appeared in the ratio of 21 pale to 7 dark. Selfing a dark form resulted in all dark purple offspring, revealing the homozygous condition of that dark colored first selfed generation plant. Selfing a pale form, on the other hand, resulted in a segregating progeny of 3 purple to 1 non-purple again, which establishes the heterozygous nature of the pale purple first selfed generation plant. The ratio of light and dark forms appearing among the purple forms was 31 to 11 which is not a significant deviation from a 2:1 ratio.

In another case, a dark purple plant, Number 12, was crossed to white, and resulted in light purple F_1 plants. The F_2 generation segregated into 3 purple to 1 white and among the purple forms 49 were light purple and 20 dark purple. This ratio fits a 2:1. Thus, it appears that the gene for purple is cumulative in its effect, that *PP* produces dark forms, *Pp*, light, and *pp*, whites. Such an additive effect of gene for the production of flower color is not new in plants. In *Nicotiana* hybrids, Smith (1937) demonstrated that the heterozygous condition has a diluting effect. Also in Dahlias (Lawrence, 1931) the two genes, *A* and *B*, that determine anthocyanin color are cumulative in their effect.

In addition to the cumulative action of gene *P* a modifying gene or genes may be operating to intensify or dilute the anthocyanin pigment, for not all flowers homozygous for *P* have the same intensity of pigment and not all segregating progenies can be subjected to simple genetic analysis. Further studies are necessary to clarify the inheritance of various intensities in coloration.

When purple flowers are crossed to yellow flowers, the purple on yellow background results in a purplish red, or bronzy color which is easily distinguishable from purple appearing on a white background. For convenience, the interaction of purple and yellow will be referred to as bronze, and purple on white background as purple. The cross between purple and yellow resulted in all bronze flowers. The F_2 generation segregated out into 9 bronze, 3 purple, 3 yellow, and 1 white, indicating that yellow and purple are independently inherited (Table 3).

PURPLEBACK. It was mentioned earlier that the anthocyanin pigment which occurs in the outer epidermal layer of the limb extends to the back of the tube. It was found that parents 2 and 16 bred true for purpleback. Parent 8, having a yellow limb with purpleback, parent 7, having white limb with purpleback, and parent 11, having purple limb with purpleback, were found to be heterozygous for this character.

Parent 16, which is homozygous for purpleback, when crossed with yellow, gave all purpleback offspring. The F_2 generation of this cross together with a few others are given in Table 4. The combined ratios of purpleback to non-purpleback was 166:56, which fits a 3:1 ratio. Purpleback, *B*, exhibits a simple dominance to non-purpleback, *b*.

Tables 5 and 6 show the dihybrid ratios between the factors *P* and *B* and *Y* and *B* respectively. In either case, the ratios obtained fit 9:3:3:1, indicating that *B* is independently inherited from genes *P* and *Y*.

Basic flower color in *A. gangetica* is governed by three sets of genes: *P*, producing

TABLE 3
THE RATIO OF BRONZE (*PY*), PURPLE (*Py*), YELLOW (*pY*), AND WHITE (*py*) FLOWERS RESULTING FROM FAMILIES HETEROZYGOUS FOR *P* AND *Y* IN *Asystasia gangetica*

PROGENY	OBSERVED				CALCULATED				CHI-SQUARE
	Bronze (PY)	Purple (Py)	Yellow (pY)	White (py)	Bronze (PY)	Purple (Py)	Yellow (pY)	White (py)	
(6 × White) Selfed	66	18	16	6	59.625	19.875	19.875	6.625	1.674
(12 × Yellow) Selfed	89	32	25	12	88.875	29.625	29.625	9.875	1.369
Total.....	155	50	41	18	148.5	49.5	49.5	16.5	2.491

Chi-square = 7.815 at 5% level.

TABLE 4
THE SEGREGATING RATIO OF PURPLEBACK TO NON-PURPLEBACK FROM FAMILIES HETEROZYGOUS FOR PURPLEBACK IN *Asystasia gangetica*

PROGENY	OBSERVED		CALCULATED		CHI-SQUARE
	Purple-back	Non-Purple-back	Purple-back	Non-Purple-back	
(16 × 5) Selfed.....	70	24	70.5	23.5	.109
(7 × 14) Selfed.....	31	8	29.25	9.75	.419
(11 × White) Selfed.....	17	7	18	6	.223
(7 × 3) Selfed.....	48	17	48.75	16.25	.046
Total.....	166	56	166.5	55.5	.007

Chi-square = 3.841 at 5% level.

TABLE 5

SEGREGATING RATIOS OF *PB* (PURPLE WITH PURPLEBACK), *Pb* (PURPLE WITH NON-PURPLEBACK), *pB* (NON-PURPLE WITH PURPLEBACK), AND *pb* (NON-PURPLE WITH NON-PURPLEBACK FROM FAMILIES HETEROZYGOUS FOR *P* AND *B* IN *Asystasia gangetica*

PROGENY	OBSERVED				CALCULATED				CHI-SQUARE
	PB	Pb	pB	pb	PB	Pb	pB	pb	
(11 × White) Selfed	11	6	6	1	13.5	4.5	4.5	1.5	1.630
(7 × 14) Selfed...	42	9	18	2	40.41	13.56	13.56	4.49	4.490
Total.....	53	15	24	3	53.46	17.82	17.82	5.94	4.048

Chi-square = 7.815 at 5% level.

TABLE 6

SEGREGATING RATIOS OF *YB* (YELLOW WITH PURPLEBACK), *Yb* (YELLOW WITH NON-PURPLEBACK), *yB* (WHITE WITH PURPLEBACK), AND *yb* (WHITE WITH NON-PURPLEBACK), FROM FAMILIES HETEROZYGOUS FOR *Y* AND *B* IN *Asystasia gangetica*

PROGENY	OBSERVED				CALCULATED				CHI-SQUARE
	YB	Yb	yB	yb	YB	Yb	yB	yb	
(7 × 14) Selfed....	25	6	6	2	21.96	7.32	7.32	2.44	.972
(7 × 3) Selfed....	33	13	15	4	36.54	12.18	12.18	4.06	1.041
Total.....	58	19	21	6	58.5	19.5	19.5	6.5	.170

Chi-square = 7.815 at 5% level.

purple pigment in the inner epidermis of limb, *B*, producing purple in the outer epidermis of limb and back of tube, and *Y*, producing yellow in the entire limb. Each of these is inherited in a simple Mendelian fashion and independently from one another. White flowers result only when all three are present as homozygous recessives. The interaction of the three genes with one another gives rise to the following eight phenotypes, when dark purple (*PP*) and pale purple (*Pp*) are classed together.

P- Y- B- bronze with purpleback
P- Y- bb bronze with non-purpleback
P- yy B- purple with purpleback
P- yy bb purple with non-purpleback
pp Y- B- yellow with purpleback
pp Y- bb yellow with non-purpleback
pp yy B- white with purpleback
pp yy bb white with non-purpleback

A plant heterozygous for *P*, *Y*, and *B* can be expected to give rise to a progeny of all eight classes in the typical trihybrid ratio of 27:9:9:3:9:3:3:1. It can be seen that from such a progeny, the chance occurrence of a white form is only one out of 64 plants. This explains the rather limited number of white forms appearing among open-pollinated seedlings in nature. Also, if the bronze forms are included with purples, the preponderance of purple-colored types is to be expected on the basis of inheritance of flower color in this species.

The genotypes of the parental plants collected for this study have been determined as follows:

Plant No.	
1	*PP YY bb*
2, 16	*PP yy BB*
3, 4, 5	*pp YY bb*

6, 14, 15	*Pp YY bb*
7	*pp yy Bb*
8	*pp Yy Bb*
9, 17, 18	*pp yy bb*
10, 13	*PP yy Bb*
11	*PP yy Bb*
12	*PP yy bb*

These plants represented all phenotypes except one, bronze with purpleback, *P Y B*.

SUMMARY AND CONCLUSIONS

The mode of inheritance of flower color in *Asystasia gangetica* Linn. was determined. Yellow flower color is dependent on gene *Y* which is dominant to white.

Two patterns of anthocyanin pigmentation exist, one in which the inner epidermis of the limb is colored, and the other in which the outer epidermis of the limb and the back of the tube are colored. The gene *P* produces the former pattern while the gene *B* is responsible for the latter. Gene *P* was determined to be additive in its effect; *PP* results in dark forms while *Pp* in light forms.

Genes *P*, *Y*, and *B* are inherited independently of one another. The dihybrid F_2 segregants fit the 9:3:3:1 ratios if the pale and dark purple forms are classed together. Where purple anthocyanin occurs together with yellow pigment, a bronzy color results. With the three genes for flower colors operating, eight basic phenotypes are obtainable. Since white flower color is due to the recessive condition of all three genes, *pp*, *yy*, *bb*, the limited number of such forms appearing in open pollinated progenies is explained.

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Spiders from some Pacific Islands

B. J. Marples[1]

Knowledge of the spiders of the Pacific is largely the result of the work of Berland (1934, *et. seqq.*). He has published a number of papers dealing with the spiders of the New Caledonian and New Hebridean region; of Samoa; and of the Marquesas, Society, and Austral groups, and other islands in the south-eastern Pacific. Recently I have completed a study of the spiders of Western Samoa (not yet published) based on two summers' collecting. It adds considerably to the list of species already known, bringing it to a total of 123 and includes several families not previously known to have representatives in the Pacific region. It is clear that much intensive collecting is needed before more than tentative conclusions can be drawn regarding the geographical distribution of spiders in the Pacific. The present paper records 31 species of spiders from the islands of Niue, Pukapuka, Rarotonga, Tokelau, Tongatabu, and Pitcairn from which few or none have been known. Forty-nine of the records are new. A new genus and two new species of Salticidae are described.

Niue is situated about 400 miles SSW of Samoa and the same distance WNW of Tongatabu. It consists of a single low-lying island some 14 miles long by 10 miles wide. I am indebted to Mr. P. T. Church for sending me specimens of five species, none having been recorded previously.

Pukapuka is an atoll in the northern part of the Cook group, 720 miles northwest of Rarotonga. It consists of several islets scattered around the reef, with an area of 2 square miles which is said to be decreasing. I am indebted to Dr. G. N. Davies for a collection of eight species, none having been recorded previously. They are all species known from Samoa.

Rarotonga is one of the Cook Islands, lying some 850 miles east of the Tonga group. It is a high volcanic island, rising to about 3,000 feet, and has an area of some 26 square miles. Berland records five species from there. I am indebted to Dr. G. H. Satchell for the present collection of nine species, which raises the total to 13. One seems to be new and is described here and tentatively placed in a new genus. The others are all known from Samoa except two, one, *Mollicia microphthalma*, recorded by Berland, the other, *Sandalodes calvus*, a new record. Both occur in the island groups to the east and then again far to the west, *M. microphthalma* in New Caledonia and Loyalty, and *S. calvus* in Australia. It is curious that neither has been found in Samoa.

The Tokelau Islands consist of a group of three atolls lying 270 miles north of Western Samoa, with areas of 1,350, 650 and 500 acres respectively. No spiders have been recorded from them. I am indebted to Dr. and Mrs. J. C. Lopdell for a collection from the island of Atafu, the smallest of the three. It consists of 13 species, all known from Samoa. The most remarkable of these is *Apiacera minuta*, one of the Ochyroceratidae, a family which has not been recorded previously in the Pacific. This species and *Conopistha unimaculata* I am describing elsewhere (Marples, in press).

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The Tonga Islands are an extensive group lying some 450 miles east of Fiji. They are very low islands, especially Tongatabu which has an area of about 100 square miles and a height of only 200 feet. Berland records 20 species, and the present collection, from Tongatabu only, includes 15, bringing the total to 31 species. One appears to be new and is described here.

Pitcairn Island does not belong to the same region as the others included here. It lies to the southeast of the Tuamotu Group, some 1,500 miles east of the Cook Islands. It is small, with an area of 1,200 acres and a height of 1,000 feet. Berland records two species and the present collection adds four more. I am indebted to Mrs. O. Clark and her family for the collection.

Measurements were made with a micrometer eyepiece, converted to millimeters and given to the nearest second decimal place. The leg formula is written as the legs in order of length above the line and the leg indices below it. For example, 1 2 4 3 indicates that Leg I is the longest and Leg III is the shortest. The leg index is calculated by dividing the length of the leg by the length of the carapace. The tibial index, giving a measure of the stoutness of the leg, is calculated by dividing the combined lengths of the tibia and patella by the breadth of the proximal end of the patella. It is given for Legs I and IV in each case. These methods of measurement follow those of Petrunkevitch. Dimensions of the abdomen, though of course not precise, are given to indicate its approximate shape.

LIST OF THE SPECIES RECORDED

DICTYNIDAE

Syrorisa mumfordi Berland. Tokelau.

ULOBORIDAE

Uloborus geniculatus Olivier. Tokelau.
Uloborus tenellus L. Koch. Tokelau.

SCYTODIDAE

Scytodes striatipes L. Koch. Tongatabu.
Scytodes marmorata L. Koch. Tongatabu.

OCHYROCERATIDAE

Apiacera minuta Marples. Tokelau.

PHOLCIDAE

Pholcus ancoralis L. Koch. Rarotonga.
Physocyclus globosus Taczanowski. Pukapuka.
Smeringopus elongatus Vinson. Tokelau, Tongatabu, Pukapuka.

CLUBIONIDAE

Clubiona samoensis Berland. Rarotonga.
Corinna sp. Pitcairn.

SPARASSIDAE

Heteropoda venatoria (Linn.). Niue, Pitcairn, Pukapuka, Rarotonga, Tokelau, Tongatabu.

SALTICIDAE

Bavia aericeps Simon. Pukapuka, Tokelau.
Menemerus bivittatus Dufour. Tongatabu.
Plexippus payculli Audouin. Tokelau.
Sandalodes calvus Simon. Rarotonga.
Ascyltus pterygodes (L. Koch). Niue, Tokelau, Tongatabu.
Athamas whitmei Cambridge. Pukapuka, Rarotonga, Tokelau.
Thorellia ensifera Thorell. Pukapuka, Rarotonga, Tokelau.
Hasarius albocircumdatus L. Koch. Tongatabu.
Trite longipalpis n. sp. Tongatabu.
Avarua satchelli gen. et sp. nov. Rarotonga.

LYCOSIDAE

Lycosa tongatabuensis Strand. Pukapuka.
Lycosa sp. Tongatabu.

THERIDIIDAE

Conopistha samoensis (L. Koch). Tongatabu.
Conopistha unimaculata Marples. Tongatabu, ?Niue.

TETRAGNATHIDAE

Tetragnatha panopea L. Koch. Tokelau.

EPEIRIDAE

Epeira theisi Walckenaer. Pitcairn, Pukapaka, Rarotonga, Tokelau, Tongatabu.

Cyrtophora moluccensis Doleschall. Niue, Tongatabu.

Nephila prolixa L. Koch. Niue, Tongatabu.

Nephila flagellans L. Koch. Tongatabu.

DICTYNIDAE

Syrorisa mumfordi Berland

4♀ imm., 1♂ imm. Tokelau. Described from the Marquesas, this species has been recorded also from Samoa. These specimens agree with those from Samoa in having 3 prolateral and 2 retrolateral teeth on the cheliceral groove, and the PME one and one-half diameters apart. Those from the Marquesas have 2 and 1 teeth and the PME are 1 diameter apart.

ULOBORIDAE

Uloborus geniculatus Olivier

9♀ and 3 imm., 4♂. Tokelau. This species seems to be more or less universally distributed in the Pacific.

Uloborus tenellus L. Koch

1 imm. Tokelau. This immature specimen apparently belongs to this species which has previously been recorded only from Samoa.

SCYTODIDAE

Scytodes marmorata L. Koch

1♀. Tongatabu. It does not seem to have been recorded previously.

Scytodes striatipes L. Koch

1♀. Tongatabu. This is the colour form with the completely chestnut-coloured carapace.

OCHYROCERATIDAE

Apiacera minuta Marples

1♀, 1♂. Tokelau. This species is described from Samoa. The family was not known previously from the Pacific, but I have specimens from Fiji, not yet determined specifically, of both *Apiacera* and another genus found in Samoa.

PHOLCIDAE

Pholcus ancoralis L. Koch

1♂. Rarotonga. New record. The species is recorded also from Samoa, Marquesas, Tahiti, and the Austral Islands.

Physocyclus globosus Taczanowski

1♀. Pukapuka. A cosmopolitan species previously recorded from Samoa and the Marquesas.

Smeringopus elongatus Vinson

1♀. Tongatabu. 11♀ and 1 imm., 1♂ and 2 imm. Tokelau. 5♀ and 1 imm., 1♂ imm. Pukapuka. 3♀. Rarotonga. 5♀. Pitcairn. A widespread species in the Pacific, but apparently not recorded previously from these localities.

CLUBIONIDAE

Clubiona samoensis Berland

1♀. Rarotonga. New record, known previously from Samoa, Tahiti, and Rapa.

Corinna sp.

1♂ imm. Pitcairn. This specimen does not have the thick pitted cuticle of *C. cetrata*, known from adjacent islands, but this might be due to its immaturity. It is included here as the family has not been recorded from Pitcairn.

SPARASSIDAE

Heteropoda venatoria (Linn.)

This species, found throughout the tropics, is often referred to as *H. regia* Fabricius, but

Bonnet (1951) has considered the question and decided that the name *H. venatoria* (Linn.) should be used. It was collected on all the islands under consideration. There is another very similar species, *H. nobilis* L. Koch, which is distinguishable most certainly by the sexual organs. An immature specimen from Rarotonga might belong to this species.

SALTICIDAE

Bavia aericeps Simon

1 ♀. Tokelau. 1 ♂ and 2 imm. Pukapuka. This species has a very wide distribution, ranging from the Marquesas and Hawaii to Malaya and the Phillipines. Compared with Samoan specimens these have a much paler abdomen, the same colour pattern being distinguishable but only very faintly marked.

Menemerus bivittatus Dufour

1 ♀, 2 ♂, and 2 imm. Tongatabu. Cosmopolitan and widespread in the Pacific.

Plexippus payculli Audouin

1 ♂ and 2 imm. Tokelau. Cosmopolitan. As compared with Samoan specimens the longitudinal dark bands extend more posteriorly on the carapace and abdomen, and the femora are less dark.

Sandalodes calvus Simon

1 ♂. Rarotonga. The species is recorded from Queensland and from the Marquesas and Tahiti, where it is common. Berland (1942) has commented on the interesting distribution in the eastern Pacific. The present new record from Rarotonga appears to be its most western occurrence in this region. To judge from Berland's figure (1933) its colour pattern is considerably paler than a specimen from the Marquesas.

Ascyltus pterygodes (L. Koch)

2 ♂. Tokelau. 2 ♀ imm. Tongatabu. 1 ♀, 1 ♂. Niue. Recorded from many islands between the Marquesas and the New Hebrides. The Tokelau specimens are slightly paler than ones from Samoa. The chelicerae of the male from Niue are more robust, darker and much more hairy than those of specimens from Samoa, and the same is true of the other appendages to a slight extent.

Athamas whitmei Cambridge

1 ♂. Tokelau. 1 ♂. Rarotonga. 2 ♀. Pukapuka. The species is recorded also from New Hebrides, Loyalty Islands, Samoa, Tahiti, Austral Islands, Mangareva, and the Marquesas. The specimen from Tokelau, as compared with ones from Samoa, Rarotonga, and Berland's figure (1935) of one from the Marquesas, is paler. The carapace between the posterior eyes is dark blue while the rest is chestnut coloured, the abdomen pale with only faint markings. Femur I is pale brown on the pro- and retrolateral surfaces. The carapace of the Samoan specimen is almost black with blue iridescence, the abdomen dark except for the red patches, and leg I is dark on both surfaces. The carapace of the Rarotongan specimen is dark chestnut. Berland (1933) records that the colour is variable and two females from Hitikau in the Marquesas were almost black.

Thorellia ensifera Thorell

3 ♀, 2 ♂. Tokelau. 2 ♀, 1 ♂. Pukapuka. 1 ♀, 2 ♂, and 1 imm. Rarotonga. This species is very widespread, from the East Indian Islands across the Pacific to Pitcairn and Henderson Islands. Berland (1935) figures a male in which the carapace is dark and the abdomen has a transverse zigzag. In specimens from Samoa the part of the carapace behind the eyes has a central dark streak, a dark margin and a horizontal dark band halfway between the eyes and the margin. The zigzag on the abdomen usually forms a broad transverse band. The Tokelau specimens are paler and the markings are scarcely discernible, whereas the others resemble the Samoan specimens except that the markings on the carapace of

those from Rarotonga are more strongly developed.

Hasarius albocircumdatus (L. Koch)

1♂ imm. Tongatabu. This specimen may belong to this species, already recorded from Tahiti.

AVARUA gen. nov.

Carapace flat above, thoracic groove small, situated halfway between the level of PLE and the posterior margin. Leg I stoutest, 3 pairs of ventral spines on metatarsi I and II and on tibia I. Tooth on the retromargin of the cheliceral groove deeply serrated.

The genus is similar to *Efate* Berland but differs in the position of the thoracic groove, the divided instead of entire retrolateral tooth and the arrangement of spines.

Type species: *A. satchelli* n. sp. It is named after the place in Rarotonga where this species was collected.

Avarua satchelli n. sp.
Fig. 1

1♂. Avarua, Rarotonga. Collected by Dr. G. H. Satchell, 1949.

MALE. Length 5.40 mm. Carapace, sternum, chelicerae, palps, and first legs yellowish brown. Carapace dark in the ocular area and round the edge, palps with a dark streak on the dorsal side of the two distal joints. Abdomen and other legs paler. Dorsal side of abdomen browner towards the anterior end and grey near the spinnerets, three pairs of lateral markings, ventral side pale.

Carapace: Length 1.60 mm., breadth 1.35 mm. Flat on top, especially the ocular area and back as far as the thoracic groove which is minute, longitudinal and situated halfway between a line joining the PLE and the posterior end of the carapace. Carapace slightly widest at the level of the second legs.

Eyes: Ratio of eyes AM:PL:AL:PM = 224: 106:102:39. Ratio of their distances apart AM–AM, 20; PM–PM, 585; PL–PL, 540; AL–PM, 158; PM–PL, 150. Breadth of anterior row of eyes 1.12 mm.

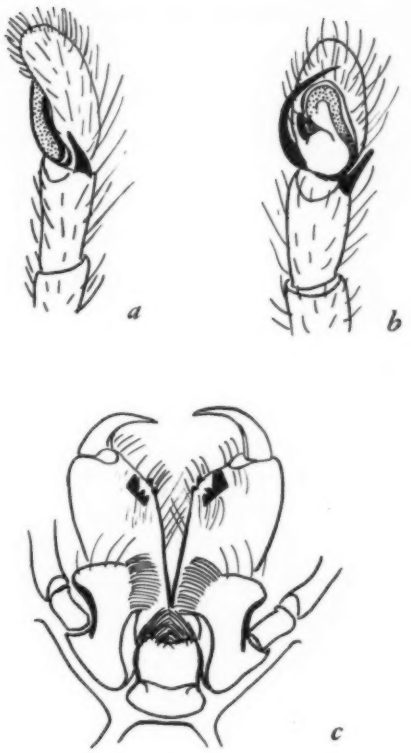

FIG. 1. *Avarua satchelli* gen. et sp. nov., male. *a*, Retrolateral view of left palp; *b*, ventral view of left palp; *c*, ventral view of mouth parts.

Chelicerae: Fissidentate. A large blade on the retromargin of the groove almost divided into 3 teeth, the dorsal one largest and with a bifurcate point. Two teeth at the ventral end of the promargin.

Maxillae: Long, the distal part much wider than the rest, its median corner with a scopula, its outer one forming a rounded lobe with a dark margin.

Lip: Longer than broad. Notched at the tip and on each side near the base for the bases of the maxillae.

Sternum: Length 0.99 mm., breadth 0.59

mm. Slightly notched opposite the bases of the legs.

Palp: Bulb small, as in Figure 1. One short spine on the dorsal side of the femur.

Legs:

1	4	2	3	palp
1.93	1.49	1.22	1.10	0.75

	FEMUR	PATELLA AND TIBIA	METATARSUS	TARSUS	TOTAL
I	1.26	1.27	0.76	0.45	3.74
II	0.86	1.16	0.47	0.33	2.81
III	0.80	0.88	0.54	0.32	2.53
IV	1.05	1.34	0.75	0.31	3.45
Palp	0.67	0.64	...	0.43	1.74

Tibial Index I 15.2
Tibial Index IV 15.3

First leg much the heaviest. Spines: Femur, none on I, other legs with a distal dorsal pair and two single proximal ones. Tibia; I, three ventral pairs, IV, one prolateral distal. Metatarsus; I and II, three ventral pairs, III and IV with one prolateral distal.

Abdomen: Length 2.72 mm., breadth 0.96 mm. Long and cylindrical. Anterior spinnerets stout and parallel, the remainder slender and radiating, arranged in a line dorsal to the bases of the anterior ones.

Trite longipalpis n. sp.
Fig. 2

1♂. Tongatabu. 1952.

MALE. Length 7.84 mm. Carapace chestnut brown, darker round the edge, with black surrounding the eyes but not in the ocular area. Chelicerae, palps, lip, maxillae, and leg I, except the tarsus, chestnut brown. Other legs and tarsus I, pale. Abdomen pale with narrow longitudinal grey streaks along the sides, interrupted by three oblique pale areas, leaving three roughly triangular pale areas on the dorsal side which decrease in size backwards. The anterior dorsal area has two grey streaks along it.

Carapace: Length 3.78 mm., breadth 3.00 mm. Rounded in outline. Small longitudinal thoracic groove behind the PLE about one-third the distance towards the posterior margin.

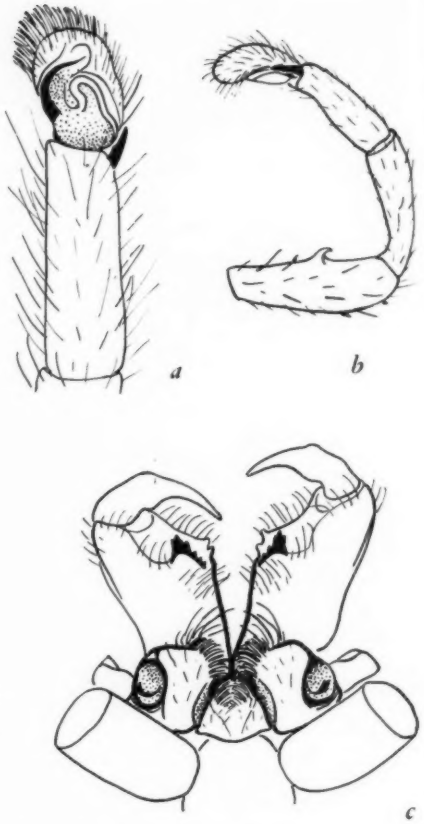

FIG. 2. *Trite longipalpis* sp. nov., male. *a*, Ventral view of left palp; *b*, retrolateral view of left palp; *c*, ventral view of mouth parts.

Eyes: Ratio of eyes AM:AL:PL:PM = 142:85:85:26. Ratio of their distances apart AM–AM, 10; AM–AL, 27; PM–PM, 406; PL–PL, 382; AL–PM, 91; PM–PL, 73. Breadth of anterior row of eyes 2.32 mm.

Chelicerae: Stout, convex on the outer (dorsal) margin where there is a dark ridge, and somewhat concave anteriorly on the prolateral surface. Prolateral margin of the groove with two teeth at its ventral end, from which a dark ridge runs along the ventral margin. In the retrolateral margin of the groove there is a concavity in the dorsal half and a large

tooth at the ventral end. This has four serrations on its ventral side and a high, slightly bifurcate tip. The basal half of the fang is stout, the distal part more slender and tapering. At the point of transition there is something of a flange which bites into the concavity on the retromargin of the groove, and a blunt elevation on the prolateral side.

Maxillae: Parallel and elongate. On the ventral surface the central third is a longitudinal elevation with distinct margins. On the median side of the elevation there is a shelf overlapped by the lip and distal to this occupied by a scopola; on the lateral side there is a large hemispherical pit with dark walls and margin.

Lip: Longer than broad, truncated distally.

Sternum: Length 1.55 mm., breadth 0.98 mm. Convex, not indented opposite the coxae.

Palp: Unusually long and leg-like with small bulb. At the centre of the ventral side of the femur is a stout hook curved distally, two distal spines on dorsal side (Fig. 2).

Legs:	1	4	2	3	palp
	2.75	1.83	1.80	1.60	1.52

	FEMUR	PATELLA AND TIBIA	METATARSUS	TARSUS	TOTAL
I	2.82	4.75	1.82	1.06	10.45
II	2.05	2.80	1.19	0.76	6.81
III	1.91	2.24	1.33	0.60	6.08
IV	2.20	2.62	1.49	0.59	6.91
Palp	1.96	2.93	...	0.86	5.75

Tibial Index I 11.3
Tibial Index IV 13.8

Spines: Metatarsus; I and II, two pairs ventral, III, distally one each pro-, retro- and ventral and one proximal prolateral, IV, three distal. Tibia; I, three ventral pairs, II, two pairs and one single, III, two distal ventral and one each pro and retro, IV, two distal and one proximal ventral, one pro- and two retrolateral. Femur; I and II, one pair distal and dorsal and two single dorsal, III and IV, three distal and dorsal and two single dorsal.

Abdomen: Length 4.18 mm., breadth 2.41 mm.

The generic allocation of this species is doubtful, but it seems to resemble *T. gracilipalpis* Berland (1929) in many ways. It differs in the palps and the teeth on the chelicerae.

LYCOSIDAE

Lycosa tongatabuensis Strand

1♀, 1♂. Pukapuka. Though smaller and paler than specimens from Samoa, they seem to belong to this species. According to Berland, it is widespread, occurring also in Tonga, Tahiti, and the Tuamotus.

Lycosa sp.

1♀. Tongatabu. This seems to be a different species with pale carapace, abdomen without pattern and legs not ringed. Legs long, especially IV. Epigynum very small. It does not seem desirable to describe this as a new species without comparative material, as many of the Lycosidae are not adequately described.

THERIDIIDAE

Conopistha samoensis (L. Koch)

2♀ and 1 imm., 2♂ and 1 imm. Tongatabu. on webs of *Nephila*. The species was described from Samoa and has been recorded also from New Caledonia, New Hebrides, and Tahiti. As in some of the Samoan specimens the dark band up the side of the abdomen is absent. The male is smaller than that from Samoa and the profile is slightly different, the eye-bearing projection being closer to the anterior one, but the palp is the same in each.

Conopistha unimaculata Marples

2♀ imm., 1♂. Tongatabu. The species was described from Samoa. A single incomplete female from Niue is much larger, but resembles this species and may belong to it.

TETRAGNATHIDAE

Tetragnatha panopea L. Koch

1 ♀ and 2 imm., 1 ♂. Tokelau. This species is recorded also from Samoa, Ellice, New Hebrides, and Lord Howe Islands. The male is smaller than a Samoan specimen but resembles it in details of palp and chelicera.

EPEIRIDAE

Epeira theisi Walckenaer

1 ♀, 1 ♂. Tongatabu. 28 ♀ and 15 imm., 5 ♂ and 4 imm. Tokelau. 5 ♀ and 5 imm., 1 ♂. Pukapuka. 1 ♀ and 1 imm. Rarotonga. This species is common and widespread throughout the Pacific. The colour of the abdomen is very variable, from almost black with a mid-dorsal longitudinal white band to a pale speckled condition, but all seem to belong to this species.

Cyrtophora moluccensis Doleschall

30 ♀. Tongatabu. 1 ♀ and 1 imm. Niue. Widespread in the Pacific.

Nephila prolixa L. Koch

1 ♀. Tongatabu. 1 ♀. Niue. This species is recorded previously from Fiji, Tonga, and Samoa. In Samoa there has been no record since that of Koch. Since it is so large and conspicuous it is unlikely to have been overlooked by both collectors and residents. Possibly the record is of one accidentally introduced and it is no longer present.

Nephila flagellans L. Koch

1 ♀ imm., 1 ♂ imm. Tongatabu. Recorded previously from Fiji and Tonga.

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Sphaeniscus Becker and *Euphranta* Loew of the Oriental and Pacific Regions[1] (Tephritidae-Diptera)

D. Elmo Hardy[2]

Reviews of the genera *Sphaeniscus* Becker and *Euphranta* Loew of the oriental and Pacific regions are presented in this study. The generic concepts of *Euphranta* have been revised and *Staurella* Bezzi is considered a subgenus of *Euphranta*. I have placed six species in *Euphranta* (*Euphranta*) and 25 species in *Euphranta* (*Staurella*). One new species in each of these groups is being described from the Philippine Islands. The drawings have been prepared by Marian S. Adachi, University of Hawaii; this help is greatly appreciated.

Sphaeniscus Becker

Sphaeniscus Becker, 1908. Berlin Zool. Mus., Mitt. 4: 138.

Spheniscomyia Bezzi, 1913, Ind. Mus., Mem. 3: 146–147 [Invalid emendation of *Sphaeniscus* Becker].

Characterized by having vein R_{4+5} bare or but sparsely bristled; by having four scutellar bristles (except for *S. neivae* (Bezzi) from Africa); the r–m crossvein situated toward the apical portion of cell 1st M_2; the arista pubescent; the cubital cell with a very short angular lower apical lobe; the postocular cilia and other cephalic bristles all black; the body shining black without yellow markings; the wings black with a pattern of hyaline spots including four to five on the hind margin and the basal portion of the wing.

Key to species of *Sphaeniscus* known from the Pacific and Oriental regions*

1. Wings with four hyaline spots on the hind margin (Fig. 1) 2
   Wings with three hyaline spots on the hind margin (S. E. Asia) . . . . . *quadrincisus* (Wied.)
2. Two hyaline spots in median portion of wing (Fig. 1) (Fiji) . . *binoculatus* (Bezzi)
   No such hyaline spots (Fig. 2) (Pacific and Orient) . *sexmaculatus atilia* (Walker)

Sphaeniscus binoculatus (Bezzi)
Fig. 1

Spheniscomyia binoculata Bezzi, 1928, Dipt. Brachycera Fiji Isl., 115–116.

This species is closely related to *S. sexmaculatus*. It is distinguished by having two round isolated hyaline spots in the middle of the wing, one situated at the upper basal third of cell 1st M_2, slightly over vein M_{1+2}, and one at the upper middle of cell R_5 (Fig. 1) rather than having the distal wedge-shaped mark on the hind margin of the wing extending through cell R_5 almost to vein R_{4+5} and the wedge-shaped proximal mark extending to the middle of cell 1st M_2 (Fig. 2). The

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* *Spheniscomyia apicalis* Shinji (1939: 322) is apparently a *Trypeta* (Ito, 1947).

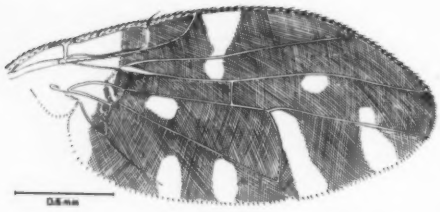

FIG. 1. Wing of *Sphaeniscus binoculatus* (Bezzi).

recumbent hairs on the mesonotum are black on the specimen of *binoculatus* at hand and the mesonotum is subshining black, thinly gray pollinose. In *sexmaculatus* the recumbent hairs on the mesonotum are yellow and the dorsum is rather thickly gray pollinose. The ovipositor appears to have a shorter piercer and basal segment than in *sexmuculatus* but it is not being described as the specimen at hand is in poor condition.

Length: body and wing, 2.5–3 mm.

Type locality: Yasawa and Cuvu, Fiji.

Type in the British Museum (Natural History).

A specimen at hand is from Lau, Fiji, Oneata, Aug. 16, 1924 (E. H. Bryan, Jr.).

Sphaeniscus sexmaculatus atilia (Walker) new comb.
Fig. 2*a–b*

Trypeta atilia Walker, 1849, List Dipt. Ins. Brit. Mus. 4: 1021.

Trypeta melaleuca Walker, 1864, Linn. Soc. Lond., Proc. 7: 238.

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Spheniscomyia sexmaculatus Shiraki, 1933, Fac. Sci. Agri. Taihoku Imp. Univ., Mem. 7(2): 354.

Spheniscomyia sexmaculata Malloch, 1939, Linn. Soc. N. S. Wales, Proc. 64(3–4): 450.

S. atilia has been considered as specifically distinct from *sexmaculatus* but I have not been able to find characteristics which appear to be of specific importance. I have compared specimens from a wide range of localities through the Pacific and Orient with those from Africa, and the coloring of the hind tibiae and the extent of the pollinosity on the mesonotum appear to be the only differences. I feel that this should be treated as a subspecies. *S. atilia* is distinguished from typical *sexmaculatus* by having the hind tibia yellow, and the pollinosity of the mesonotum not arranged in a definite pattern. Typical *sexmaculatus* has the hind tibia nearly all black, yellow only on the apex, and the mesonotum with the pollen arranged into four rather distinct longitudinal gray vittae. The scutellum and the sides of the mesonotum are very lightly dusted, shining black in most lights. The pollinose lines are not clearly visible if viewed directly from above but stand out if the specimen is examined at an angle toward the head. Munro (1938: 36) and Chen (1947: 103) have indicated that the proximal hyaline marginal spot of the wing is narrower in *atilia* than in *sexmaculatus;* I have not been able to demonstrate any significant differences in the wing pattern (Fig. 2*a*). It also should be noted that when specimens of *atilia* are examined in the same position suggested for *sexmaculatus* faintly shining vittae are seen to be present, also the hind tibiae may be discolored basally in some specimens. Malloch's specimens from the Admiralty Islands and Papua (1939: 450) were evidently of this type. The characters of the ovipositor of *S. sexmaculatus atilia* are as in Fig. 2*b*.

This subspecies is widespread over the Orient and much of the Pacific. I have studied specimens from the following localities. Philippine Islands: Mindoro, Feb. 1945 (F. E. Skinner); Tacloban, Leyte (Baker); Los Baños (Baker) and Baguio, Benquet (Baker). Malaya: Kuala Lumpur, July–August, 1948, ex flower heads of *Hyptis capitata* (N. L. H. Krauss). India: Tanakpur, U. P., November,

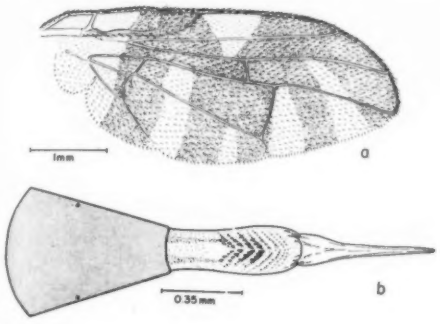

FIG. 2. *Sphaeniscus sexmaculatus atilia* (Walker). *a*, Wing; *b*, ovipositor.

1949 (N. D. Waters) and Ranikhet, U. P., July, 1949, on flowers (F. A. Bianchi). Ryukyu Islands: Ishigaki, December, 1952 (G. E. Bohart). China: Suisapa, Lichuan Dist. W. Hupeh, 1,000 m., July, 1948, and Sang-Hou-Ken to Mo-tai-chi, Hupeh, July, 1948.

EUPHRANTA Loew

Euphranta Loew, 1862. Mon. Europ. Bohrfl., p. 28.

This genus is recognized by the presence of fine hairs on the pleuroterga (the lateral divisions of the metanotum); by the absence of ocellar, presutural, and prescutellar bristles (in *Euphranta* (*Euphranta*)); by having strong sternopleural and two to three pairs of inferior fronto-orbital bristles. *Staurella* Bezzi appears to be a subgenus of *Euphranta*, the only satisfactory character which I have found for separating them is the presence or absence of the prescutellar bristles. Some of the literature dealing with these flies has contained some obvious errors which have confused the generic concepts. Bezzi (1913: 122) and Hendel (1927: 68) stated that dorsocentral bristles are absent in *Euphranta*. Hendel previously (1914: 80) said that dorsocentrals were absent, at least in the females. I have studied the genotype and a number of other species, and descriptions of species, and have found none which has no dorsocentrals; all, however, have lacked prescutellars in both sexes. I believe Bezzi and Hendel were actually referring to the prescutellar rather than the dorsocentral bristles. Chen (1947: 80), following Bezzi, indicated that *Euphranta* lack dorsocentral bristles. Hering (1938: 24) made the same statement except that the lack of dorsocentrals was included parenthetically and was attributed to Hendel and he said that because of their position he was of the opinion that Hendel was referring to prescutellar bristles. Chen (*op. cit.*: 85) said that *Euphranta* may also be distinguished from *Staurella* by having the base of vein R_{4+5} distinctly bristled, in contrast to *Staurella* which has R_{4+5} bare. Bezzi (1913) used this character in separating *Staurella* but indicated that it may be variable. I have found this character to be very inconsistent, bristles are present at the base of R_{4+5} in most of the species of *Staurella* which I have studied. A number of other characters have been mentioned as useful in separating these groups: The position of the r–m crossvein, whether it is before or after the middle of the discal cell; the position of the dorsocentral bristles in relation to the anterior supraalar bristles; the comparative length of the subcostal cell and the shape of the third antennal segment. I have checked these characters through all of the available species of both groups and have found them to be of no value in separating these groups. In veiw of this and in the absence of any apparent characters which are consistent, other than the presence or absence of prescutellar bristles, it would seem more proper to consider *Staurella* as a subgenus of *Euphranta*. The genus *Staurocneros* Hering is close to *Staurella* and might also prove to be a subgenus of *Euphranta*. Hering distinguished it thus: the first section of the costa as long or longer than the second, the dorsocentral bristles situated just slightly behind a line drawn between the anterior supraalars; the m crossvein situated beyond the middle of cell 1st M_2; the arista short haired; and the second tibia having only one long apical spine. Some of these may not be

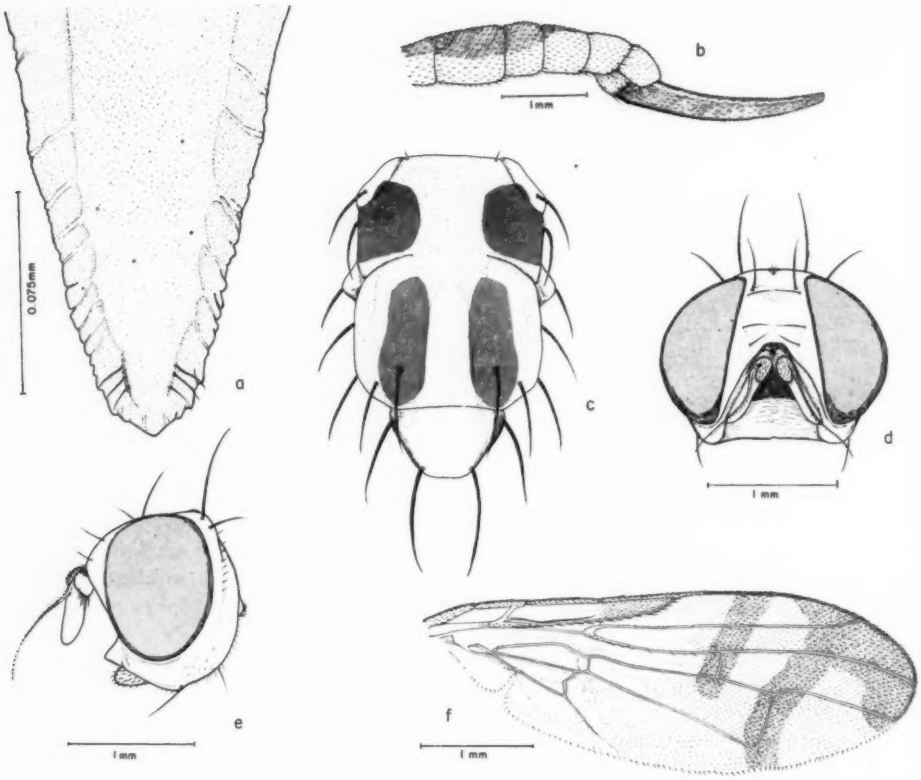

FIG. 3. *Euphranta skinneri* n. sp. *a*, Apex of piercer; *b*, lateral aspect of abdomen and basal segment of ovipositor; *c*, dorsal aspect of thorax; *d*, frontal aspect of head; *e*, lateral aspect of head; *f*, wing.

constant, *Staurocneros punctilabris* (Bezzi) has two apical spines on the middle tibia.

Genotype: *Euphranta connexa* (Fabricius).

The genus is largely oriental and Pacific in distribution although one species is perhaps present in the Ethiopian region. I have been able to place the following species in this subgenus: *E. connexa* (Palaearctic and Indo-australian); *E. flavorufa* Hering (Manchuria); *E. maxima* Hering (Borneo); *E. naevifrons* Hering (Sunda Isls.); *E. scutellata* Malloch (Solomon Isls.) and *E. skinneri* n. sp. (Philippine Isls.). The following species have not been properly placed: *E. hammersteini* Enderlein (Madagascar); *E. minor* Hendel (Australia) and *E. nigra* Enderlein (Sumatra). Most of the species described as *Euphranta* belong in *E.* (*Staurella*). *Euphranta latilimbata* Enderlein has been placed in *Staurocneros*.

One new species is at hand.

Euphranta skinneri n. sp.

Fig. 3*a–f*

This species is very closely related to *Euphranta maxima* Hering, from Borneo (Hering, 1941: 14–15). The two differ in body coloration and markings; in wing markings and in the length of the ovipositor. The most obvious character for separating *skinneri* is that

the basal brown spot on the costal margin occupies only the subcostal cell and does not extend through cell R_2 to vein R_3 as it does in *maxima*. The thorax is predominantly yellow, not yellow-brown, and the paler markings of the thorax, described by Hering as "hellgelben," are whitish, just faintly yellowed. The front is yellow in *skinneri*, with a faint brownish discoloration in the middle; not with a velvety black spot as in *maxima*. The whitish median stripe on the mesonotum ends before the suture in *skinneri*, in *maxima* it extends beyond the suture, halfway between the presutural and the scapular bristles. The first abdominal tergum is rufous medially in *skinneri* and is all black in *maxima*. In the female of *skinneri* the dark brown to black stripes which extend down the sides of the dorsum converge on tergum five and extend as a median line to the apex of the sixth tergum. In *maxima* the side stripes extend to the middle of the fifth tergum and the sixth is entirely yellow-brown.

Dr. Hering in correspondence, has supplied the following corrections to his description of *maxima*. He says that the second antennal segment, not the third, is dark brown, not black. He also says that the oviscapt in *maxima* is longer than the remainder of the abdomen, not equal to it (120:100). In *skinneri* the basal portion of the ovipositor is shorter than the abdomen (60:80).

MALE

Head: Almost all yellow with a tinge of brownish in the middle of the front. The front is broadest at the lower portion and is slightly narrowed near the ocelli, at the broadest point it is equal in width to or slightly broader than one eye. Three pairs of inferior fronto-orbital and one pair of superior fronto-orbital bristles are present. Ocellar bristles are lacking; the post vertical bristles are small and converged (Fig. 3*d*). The face is entirely clear yellow and slightly concave as seen in lateral view. The first antennal segment is small and inconspicuous and is largely hidden by the forward development of the head which covers the bases of the antennae. The second antennal segment is almost one-half as long as the third. The first and second segments are densely covered with short, black bristles on the dorsal surface (Fig. 3*e*). The basal segments are yellow to rufous. The third segment is entirely yellow, is densely pubescent and obtusely pointed at apex (Fig. 3*e*). The arista is rather thickly plumose. The palpi are all yellow, are rather thickly covered with short, black bristles, especially on the ventral portion, and are just slightly larger than the third antennal segment. The occiput is all yellow.

Thorax: Yellow except for four large polished black spots on the mesonotum, except for the shining black metanotum, except for a large brown spot on each hypopleuron and for a narrow longitudinal stripe which extends through the middle portion of each mesopleuron across the top edge of the proepimeron. The black markings of the mesonotum are arranged as follows: covering the entire area, on each side, from the hind margin of the humerus to the suture; with a pair of broad postsutural submedian black vittae extending to the scutellum and extending laterally to the bases of the inner supraalar bristles. Prescutellar bristles are lacking. Three pairs of supraalar and one pair of dorsocentral bristles are present. The dorsocentrals are situated in front of a line drawn between the inner supraalars but are much closer to the inner than to the anterior supraalars (Fig. 3*c*). The humeral bristles are well-developed. There is also a strong bristle on the upper portion of each sternopleuron. Four strong scutellar bristles are present.

Legs: Almost entirely rufous, the front tibia is slightly discolored with brown.

Wings: Predominantly hyaline, with a very faintly brownish tinge at the base; the stigma is yellow-brown, and a faint tinge of brown extends over the forking of the radial sector. A brown vitta extends transversely over the wing from the median portion of cell R_2 over the r–m crossvein and about halfway through

cell 1st M_2. The entire apical portion of wing is brown. An arm of this marking extends transversely over the wing across the m cross-vein to the wing margin (Fig. 3*f*). The cubital cell has a very short, acute point on the lower apex. Vein Cu_1 + 1st A is very slightly curved and extends to the wing margin.

Abdomen: Chiefly yellow to rufous, with a black stripe extending longitudinally down the sides from the first to, and including, the fourth tergum. The fifth tergum is entirely yellow to rufous and has a strong ring of black bristles at its apex. The anal area (tenth segment, proctiger) is greatly extended and elongate. It is strongly convex dorsally. The ventro-apical lobes of the ninth tergum are also very elongate.

Length: body, 8.5 to 8.8 mm.; wings, 7.5 mm.

FEMALE

Fitting the description of the male except that the lateral black vittae of the abdomen converge on the middle portion of the fifth abdominal segment and extend as a single median black vitta to the end of the sixth tergum.

Ovipositor: Dark brown to black and very prominent. The visible portion (*in situ*) is equal in length to the combined lengths of abdominal segments three to six (Fig. 3*b*). The extended ovipositor is about 6.5 mm. long, the basal segment is comparatively long and slender, 3.0 mm. by 1.0 mm. at its widest point. The spiracles are situated about 0.62 mm. from the base of the segment. The inversion membrane is damaged on the specimen which has been relaxed, it apparently is about 1.8 mm. by 0.21 mm. at its widest point. The rasper extends to within about 0.42 mm. of the base of the segment. The piercer is 1.7 mm. by about 0.15 mm. at its widest point. The apical portion is serrate (Fig. 3*a*). Three tiny inconspicuous setae are situated just before the apex. The opening of the oviduct is about 0.15 mm. from the apex of the segment.

Holotype male, allotype female, and nine paratypes, six males and three females, from Pangi, Mindanao, Phil. Is., March, 1950, ex Cucurbitaceae (F. E. Skinner). The type and allotype are being deposited in the United States National Museum. The paratypes are being deposited in the following collections: Bernice P. Bishop Museum, British Museum (Natural History), Hawaiian Sugar Planters' Association, and the University of Hawaii.

EUPHRANTA (STAURELLA) Bezzi, n. comb.

Staurella Bezzi, 1913, Ind. Mus., Mem. 3: 121–122.

I am considering this as a subgenus of *Euphranta* inasmuch as the only reliable character I have found for separating it has been the presence of the prescutellar bristles (see discussion under *Euphranta*). Much confusion has existed in the literature regarding the status of this group; most of the species have been described under *Euphranta*. The following species apparently belong in *Euphranta* (*Staurella*): *E. apicalis* Hendel (Orient); *E. camelliae* (Ito) (Japan); *E. canangae* n. sp. (Philippine Islands); *E. chrysopila* Hendel (Formosa); *E. corticicola* (Hering) (Java); *E. conjuncta* Hendel (Ceylon); *E. crux* (Fabricius) (Orient); *E. dissoluta* (Bezzi) (India); *E. jucunda* Hendel (Formosa); *E. lemniscata* Enderlein (Orient and Micronesia); *E. licenti* Zia (China); *E. linocierae* Hardy (Australia); *E. luteifasciata* (Senior-White) (Ceylon); *E. maculifemur* (de Meijere) (Sumatra); *E. maculifrons* (de Meijere) (Java); *E. mediofusca* (Hering) (Bismark Archipelago); *E. mikado* Matsumura (Japan, China); *E. nigrescens* (Zia) (China); *E. nigripeda* (Bezzi) (India); *E. nigrocingulata* (Hering) (Burma); *E. oshimensis* (Shiraki) (Japan); *E. oshimensis* "form" *separata* (Ito) (Japan); *E. rivulosa* Bezzi (Fiji); *E. sexsignata* Hendel (Formosa); *E. suspiciosa* (Hering) (Burma); *E. suspiciosa scutellaris* (Chen) (China) and *E. zeylandica* Senior-White (Ceylon).

Staurella circumscripta Hering and *S. flavina*

Hering have been placed in the genus *Staurocneros*.

Genotype of *Staurella: S. crux* (Fabricius).

One new species is at hand from the Philippines.

Euphranta (*Staurella*) *canangae* n. sp.
Fig. 4*a–d*

This species appears to be closely related to *Euphranta* (*Staurella*) *linocierae* Hardy from Australia but the coloration of the wing and body, and the wing venation differ considerably in the two species. The most striking differences are as follows: in *canangae* the subcostal cell is short, about half as long as the second costal cell and vein R_{1+2} ends well before a point opposite the r–m crossvein, in *linocierae* the subcostal cell is about three-fourths as long as the second costal cell and R_{1+2} ends beyond r–m; in *canangae* the hyaline mark which extends from the median portion of the costa is situated before the r–m crossvein and extends only to vein R_{4+5}, in *linocierae* it is situated beyond r–m and extends almost to the posterior margin of the wing; in *canangae* the r–m crossvein is situated beyond the middle of cell 1st M_2, in *linocierae* before the middle; in *canangae* the hyaline spot on the costal margin near the end of cell R_2 is separated from the median hyaline spot by a distance equal to or greater than two times its length (Fig. 4*a*), rather than being narrowly separated from the median mark by less than its length as it is in *linocierae;* no hyaline spot is present in cell 2nd M_2 of *canangae*, whereas in *linocierae* a spot is present (Hardy, 1951: 177, Fig. 28*b*).

MALE

Head: Largely yellow to rufous, with slight brownish discoloration in the median portion of the front. The front is about two times longer than wide and has three pairs of strong inferior fronto-orbitals and one pair of superior fronto-orbital bristles. The post vertical bristles are moderately strong, and are about half as long as the superior fronto-orbitals.

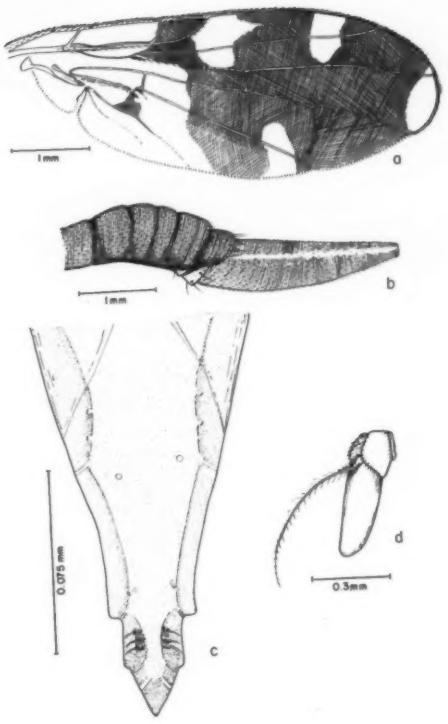

FIG. 4. *Euphranta* (*Staurella*) *canangae* n. sp. *a*, Wing; *b*, lateral aspect of abdomen and basal segment of ovipositor; *c*, apex of piercer; *d*, antenna.

The face is concave in profile and is unmarked. The antennae are reddish yellow, the arista is long pubescent. The third segment is about two times longer than wide and is slightly narrowed apically (Fig. 4*d*).

Thorax: The mesonotum is chiefly reddish brown, the median portion is yellowish in ground color and the mesonotum has a narrow yellow vitta extending down each side from the suture to the hind margin. A broad yellow vitta also extends on each side from the scutellum through the area between the inner supraalar and the dorsocentral bristles cephalad to just beyond the inner supraalars. The humeri and the area between them and the notopleura are yellow. The dorsocentral

bristles are situated closer to a line drawn between the posterior supraalar bristles than to one drawn between the inner supraalars. The pleura are yellow to rufous. The mesopleura each have three bristles near the upper margin. One sternopleural bristle is present. The scutellum is reddish brown in the median portion (between the median bristles) and is yellow on the sides. The metanotum is black. The pleuroterga are thickly covered with fine yellow hairs. The halteres are yellow.

Legs: Entirely rufous.

Wings: As in Figure 4*a*.

Abdomen: Almost entirely reddish brown, rather polished, on the dorsum, yellow on the venter; with a median yellow vitta extending down the dorsum from the base over segment four, and with the sides of terga one to three narrowly yellow. The fifth tergum has a row of strong black bristles at its apex. The genitalia are rather small and inconspicuous, mostly concealed within the broad fifth tergum.

Length: body, 6.3 mm.; wings, 5.5 mm.

FEMALE

Fitting the description of the male except for genital characters. The ovipositor is elongate and very distinctive. The basal portion (*in situ*) is about equal in length to the remainder of the abdomen (Fig. 4*b*). The extended ovipositor is about 7.2 mm. long. The basal segment is 2.7 mm. long by 1.2 mm. at its widest point. The spiracles are situated midway of the segment, about 1.2 mm. from the anterior lateral margins. The inversion membrane is about 2.48 mm. long by 0.27 mm. at its widest point. The rasper is situated approximately 0.41 mm. from the base of the segment. The piercer is 2 mm. long by 0.13 mm. and the oviduct opens about 0.2 mm. from the tip. The piercer has two preapical notches on each side (Fig. 4*c*) but apparently has no preapical setae.

Holotype male, Los Baños, Philippine Islands, Mar. 1947, ex ilang-ilang [ylang-ylang, *Cananga odorata* (Lam.)] (L. B. Uichanco). Allotype female and four paratypes, 3 males, 1 female, same data as type and one paratype female, Bohol Is., P. I., January, 1948 (Q. C. Chock).

The type and allotype are in the United States National Museum collection. The paratypes are in the following collections: Bernice P. Bishop Museum, Territorial Board of Agriculture and Forestry, Honolulu, and University of Hawaii.

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The Development of *Kerguelenella stewartiana* (Powell) (Gastropoda: Siphonariidae)[1]

G. A. KNOX[2]

A SPECIES OF SIPHONARID, *Kerguelenella stewartiana*, was described from Stewart Island by Powell in 1939. During December, 1950—January, 1951, I spent several weeks investigating the intertidal ecology of the rocky shores of Stewart Island in the vicinity of Half Moon Bay. *Kerguelenella* was found in two localities, Akers Point and Ringa Ringa. Powell records the species from Akers Point (the type locality) as, "common on seaweed-covered rocks towards high water" and from Mason Bay on the west coast of the Island, from, "low water under stones."

A striking feature of the distribution of *Kerguelenella* was that it was found only in the form of isolated colonies with a restricted horizontal range. Intensive search over about ten miles of coastline from Horseshoe Bay to the upper end of Paterson Inlet failed to reveal any further colonies. The vertical distribution of the species is also interesting. Both colonies were on more or less exposed rocks facing southeast. The Akers Point colony was found on the vertical seaward faces of large broken rocks, and the Ringa Ringa colony on the seaward side of a large isolated rock mass rising from a broken platform at about mid-tide level. All the specimens found lay in a zone extending 4 feet upward from the upper foot of the zone occupied by the red seaweed, *Bostrychia arbuscula*. This species is a conspicuous feature of the intertidal zonation of the Stewart Island region, forming a well marked band up to 3 feet in vertical extent, the upper limit lying in the vicinity of extreme high water spring tides. The vertical distribution of *Kerguelenella* thus lies above mean high water spring tides and no specimens were found below this level.

Hubendick (1946) records *Kerguelenella stewartiana* from Port Ross, Auckland Islands, "under stones at low tide level." Powell (1939), however, regarded the Stewart Island species as endemic. Judging from the observed habitat of *Kerguelenella* at Stewart Island the record of the species from "under stones at low water" is erroneous. R. K. Dell in correspondence states that he has never seen a specimen of *Kerguelenella* under stones at the Bounty Islands, Antipodes Islands, or Stewart Island, and that they are always found on rock faces near high tide.

On January 16 several small ovoid egg masses were found near the upper limit of the *Bostrychia arbuscula* zone of the Ringa Ringa colony of *Kerguelenella*. They were fastened singly or in groups of two to four to the sides of small crevices. Several were removed and subsequent examination under a dissecting microscope showed that some contained a number of limpet-like larvae in an advanced stage of development, with brown shells resembling small specimens of *Kerguelenella*

[1] The collection of the material for this study was made possible by a travelling grant from the Research Committee of the University of New Zealand. Manuscript received April 14, 1954.

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which were taken from the adjacent rock surface. Some of the egg masses were preserved in formalin and Bouin's fluid, three were placed in a glass tube which was plugged with damp cotton wool. Ten days later at Christchurch when the tube was opened several larvae had hatched. The contents of the tube were transferred to a finger bowl of sea water and the larvae remained alive for 9 weeks, during which time about 20 hatched. Many of the newly hatched larvae were found just above the water line on the side of the finger bowl.

DEVELOPMENT

The egg masses are roughly circular or oval, about 12 mm. in diameter and 6 mm. in height. (Fig. 1*a*, *b*). Each rather tough, gelatinous, transparent egg mass contains from 9 to 35 ovoid egg cocoons, filled with a yellowish albumen. The cocoon wall is tough and in many cases the fixative penetrated poorly. After staining with Gower's aceticalum carmine and clearing it was found that some of the cocoons contained early larvae, the earliest stage present being an advanced veliger 0.14 mm. long, in an egg capsule 2 mm. in its greatest diameter (Fig. 1*d*). Because of the poor fixation details of the structure of the veliger could not be seen, particularly the structure of the shell which had collapsed and crumpled in all the specimens examined. However, it was possible to see that the veliger (Fig. 1*e*) is provided with a well-developed, ciliated, bilobed velum.

The veliger stage is passed within the egg mass, the larva hatching in the crawling stage. The next stage present was a post veliger 0.60 mm. long (Fig. 1*b*). From this stage there is little change in structure apart from increase in size. When the larvae leave the egg masses they are approximately 1.5 mm. long, quite colourless except for two black eyes (Fig. 1*f*, *i*). The shell is horny, brownish, semi-transparent with well-marked growth rings (Fig. 1*g*).

The smallest individuals taken from the adjacent rock surface were 4.5 mm. long (Fig. 1*j*,*k*). A random sample of 34 individuals gave the following size distribution:

Length (mm.)	Number
4.5– 5.5	6
6.0– 7.0	0
7.5– 8.5	7
9.0–10.0	0
10.5–11.5	5
12.0–13.0	4
13.5–14.5	8
15.0–16.0	4

The largest individual found in the colony was 15.5 mm. long.

DISCUSSION

Hubendick (1946) lists some 60 species belonging to the Siphonariidae. He recognizes 2 genera, *Williamia*, with 4 species, and *Siphonaria*, with 59 valid species. On the basis of comparative anatomy he divides the Genus *Siphonaria* into 10 natural groups, namely, *Liriola*, *Pachysiphonaria*, *Benhamina*, *Kerguelenia*, *Patellopsis*, *Simphisiphonaria*, *Ductosiphonaria*, *Heterosiphonaria*, *Sacculosiphonaria*, and *Siphonaria*. Other workers consider some of these as genera.

There appears to be confusion concerning the status of some of the New Zealand species of Siphonariidae. Powell (1946), following Suter (1913–15) recognized three genera and five species for New Zealand, *Siphonaria australis* Quoy and Gaimard, *Siphonaria cookiana* Suter, *Siphonaria zelandica* Quoy and Gaimard, *Benhamina obliquata* (Sowerby), and *Kerguelenella stewartiana* (Powell). Hubendick, however, did not recognize *S. zelandica* as a separate species considering it to be a synonym of *S. australis*. An examination of shell characters and genitalia of specimens from many localities has shown that there are three species of *Siphonaria* in New Zealand. *S. zelandica* appears to be a distinct and valid species and, as Powell (1946) noted, the specimens assigned by Hubendick to *S.* (*Simphisiphonaria*) *cookiana* belong to *S. zelandica*, since the gen-

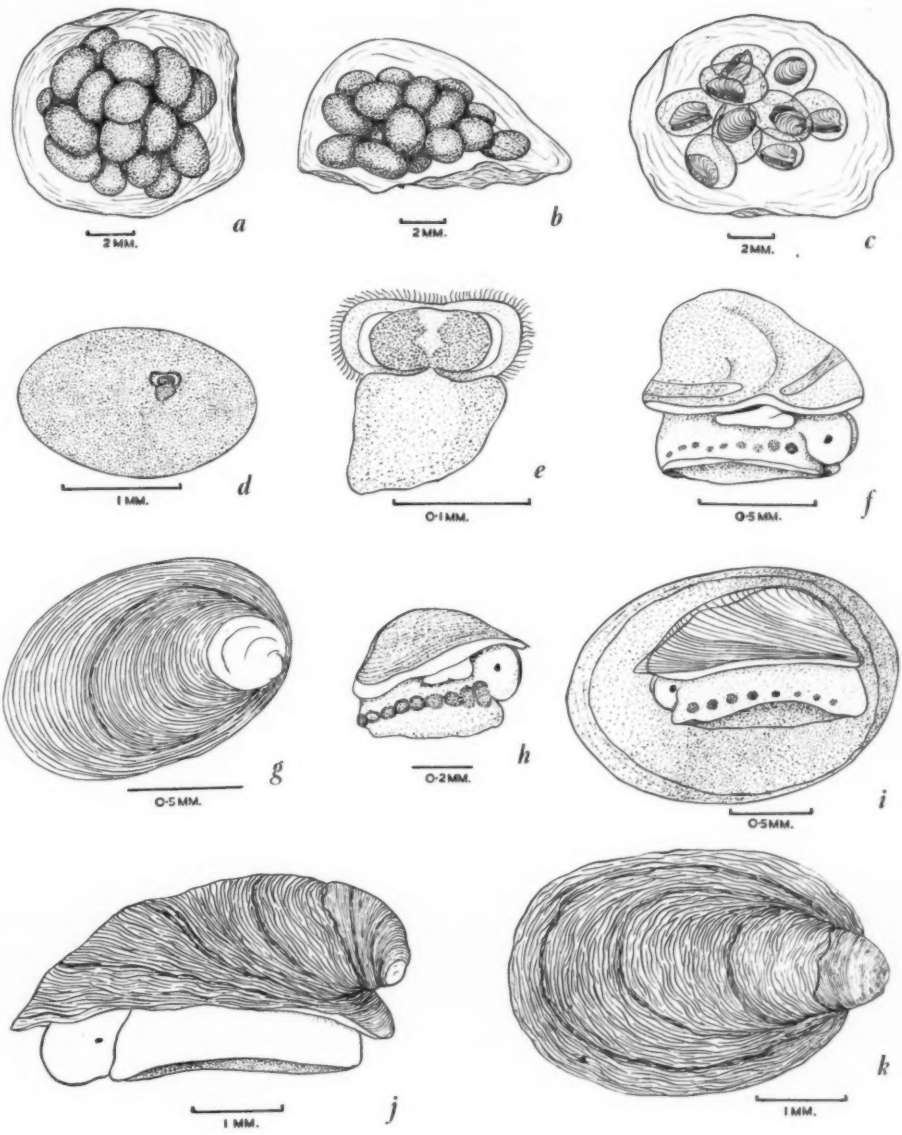

FIG. 1. Stages in the development of *Kerguelenella stewartiana* Powell. *a*, Egg mass from above; *b*, egg mass from the side; *c*, egg mass with fully developed larvae; *d*, egg cocoon with fully developed veliger (from stained material); *e*, veliger (from stained material); *f*, fully developed larva with the shell removed; *g*, larval shell; *h*, smallest post-veliger found in the egg cocoon; *i*, fully developed larva ready to emerge (part of the wall of the egg cocoon has been cut away); *j*, smallest individual taken from the rock surface; *k*, shell of the same individual.

italia he figures (Fig. 12, p. 14) are those of the latter species. The genitalia of the true *S. cookiana* are quite distinctive.

A search through the literature shows that the development of only six species of Siphonariidae is known. These are: *S.* (*Simphisiphonaria*) *zelandica* Quoy and Gaimard from New Zealand, described by Hutton (1882) as *S. australis* Quoy and Gaimard; *S.* (*Patellopsis*) *pectinata* (L.) from the Southern Mediterranean, described by Dieuzeide (1935) as *S. algesirae* Quoy and Gaimard; *S.* (*Sacculisiphonaria*) *japonica* (Donovan) from Japan, described by Abe (1939) as *S. atra* Quoy and Gaimard; ? *S.* (*Sacculosiphonaria*) *cochleariformis* Reeve from Japan, described by Fujita (1904) as *S. lepida* Gould; *S.* (*Patellopsis*) *belcheri* Hanley from the Persian Gulf, described by Thorson (1940) as *S. sipho; S.* (*Siphonaria*) *kurracheensis* Reeve also described by Thorson (1940) from the Persian Gulf. Of these the last species has a non-pelagic development, the others a pelagic larval stage. In addition observations by Borland (1949) on *Benhamina obliquata* and by myself on *S. cookiana* and *S. australis* indicate that these three species also have a pelagic larval stage. The development of representatives of only four of the ten groups into which Hubendick divides the Genus *Siphonaria* is known, and to date the development of the *Kerguelenella* group, which consists of four species having a circumantarctic distribution has remained unknown.

Among the species of Siphonariidae for which the development is known *K. stewartiana* is notable for the size of the egg and the small number of eggs in the egg mass. Table shows a comparison of the eggs of K. stewartiana and three other species.

S. (*Siphonaria*) *kurracheensis*, the other species with direct development, also occurs at or above the high water level. The species with a pelagic larval stage all occur below high water in the intertidal zone proper.

In *S.* (*Patellopsis*) *pectinata* (Dieuzeide, 1935) and *S.* (*Simphisiphonaria*) *zelandica* (Hutton, 1882) the larval shell appears to be lost and does not form part of the adult shell. In *K. stewartiana* as in *S. kurracheensis* (Thorson, 1940) and *Williamia vernalis* (Hubendick, 1946) the larval shell forms the upper part of the adult shell (Fig. 1*l*,*k*).

TABLE 1
SIZE OF EGG MASS, NUMBER OF EGGS, AND SIZE OF EGG OF SEVERAL SPECIES OF SIPHONARIIDAE

SPECIES	SIZE OF EGG MASS	NUMBER OF EGGS PER MASS	SIZE OF EGG
K. stewartiana	12 mm.	12–25	2.00/1.35 mm.
S. kurracheensis	12 mm.	Hundreds	0.50/0.38 mm.
S. belcheri	25 mm.	Numerous	0.25/0.17 mm.
B. obliquata	25–50 mm.	45,000–190,000	Unknown

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Additional Records to the Flora of Johnston Island

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PREVIOUS ACCOUNTS of Johnston Island plants have been from the field notes of Edwin H. Bryan Jr. published by Christophersen (1931) and additional records published by Fosberg (1949).

In January, 1954, the United States Air Force provided the author with transportation and quarters for a brief study of the atoll. The following list of new records to the flora is one result of this visit. The list is of two parts: (1) Plants growing without apparent cultivation and of which specimens were collected, (2) plants which were noted in dependents' homes and gardens. All determinations of plants not under cultivation were made by Dr. Harold St. John of the University of Hawaii. No specimens of plants under cultivation were taken from the sparse population maintained perhaps only by daily watering. A mint, an araceous plant and "mother-in-law's tongue" are not included for lack of more specific field determination.

PLANTS NOT UNDER CULTIVATION

Acacia farnesiana (L.) Willd.
Amaranthus dubius Mart.
Araucaria excelsa (Lamb.) R. Br.
Calophyllum inophyllum L.
Catharanthus roseus (L.) G. Don
Chenopodium murale L.
Coccoloba uvifera (L.) Jacq.
Cordyline terminalis (L.) Kunth
Eragrostis amabilis (L.) Wight & Arn.
Erigeron bonariensis L.
Euphorbia hirta L.
Euphorbia glomerifera (Millsp.) L. C. Wheeler
Hibiscus tiliaceus L.
Ipomoea pes-caprae (L.) Sweet
Nicotiana glauca Graham
Pedilanthus tithymaloides (L.) Poit.
Sesuvium portulacastrum (L.) L.
Solanum lycopersicum L.
Sporobolus virginicus (L.) Kunth
Thevetia peruviana (Pers.) Schumann

PLANTS UNDER CULTIVATION

Allium fistulosum L.
Allium sp.
Alpinia sp.
Anthurium andraeanum Lind.
Bougainvillea sp.
Capsicum frutescens L.
Carica papaya L.
Citrullus vulgaris Schrad.
Citrus aurantifolia (Christmann) Swingle
Codiaeum variegatum (L.) Bl. var. pictum (Lodd.) Muel.-Arg.
Euphorbia pulcherrima Willd.
Gardenia sp.
Merremia tuberosa (L.) Rendle
Lobularia maritima (L.) Desv.
Mangifera indica L.
Pandanus sp.

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Persea americana Mill.
Plumbago auriculata Lam.
Plumeria acuminata Ait.
Vanda sp.

Fosberg (personal communication) reports that he found *Vernonia cinerea*, *Brassaia actinophylla*, and *Schinus terebinthifolius* in 1949. These were not seen at the time the present study was made.

It is not surprising to find such an increase in the number of species. Daily plane flights to and from other Pacific areas allow for many accidental as well as intentional introductions. A number of the records are based on but a few specimens in what may be considered a transient population.

Records of the United States Weather Bureau from April, 1952, to February, 1954, indicate that the annual rainfall on Johnston Island is less than 20 inches. It might be of value to note in the future the species not surviving under such dry conditions.

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News Notes

Vegetation of the Society Islands and Makatea, by H. R. Papy.

Those interested in the geography and natural history of the islands of the Pacific will welcome the appearance of the first part of a detailed study of the vegetation of a large part of French Oceania by H. René Papy, who spent several years in an administrative capacity in Tahiti. This work, entitled, *La vegetation des Iles de la Societe et de Makatea (Oceanie francaise),* is published by the Laboratoire Forestier de Toulouse, Faculté des Sciences, Université de Toulouse, Allée Saint Michel, Toulouse, France. It is in two parts, the first of which is ready for distribution. This first part includes detailed chapters summarizing all available information on the physical geography and geology, climatology, and soils, as well as a topographic map of the islands. It is abundantly illustrated by small maps, diagrams, and photographs. In this first part, however, there is little on vegetation, except for the photographs. The second part, in manuscript, is a detailed study of the vegetation. itself. The publication of the latter will depend on the proceeds from sales of the first part. It is hoped that this will not be long delayed. — F. R. F.

Coe, Wesley R. *Bathypelagic Nemerteans of the Pacific Ocean.* Scripps Institution of Oceanography of the University of California, Bulletin. Vol. 6, No. 7, pp. 225–286, 2 pls., 32 figs. University of California Press, Berkeley and Los Angeles. $0.75.